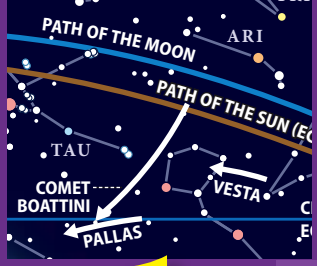
INSIDE pullout star charts



Is **NASA** on the right track with its **search for life?** p. 28

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Wolf-Rayet stars are big, hot, and bright. They might solve mysteries of the universe's biggest blasts. p. 34

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What has *your* dealer done to save you money? Here's what Astronomics has done in the past . . .

No other telescope dealer has worked harder to save you money over the past 30 years than Astronomics. Consider . . .

When manufacturers have too much inventory, they come to us *first* with special deals on their overstock. Because we can often buy all they have, we get them at low prices that let us sell to you for way less than regular retail. For example . . .

We bought Celestron's entire inventory of over 600 CR150HD 6" refractors. They had been selling for $1199. We sold them for $699 – saving you $500.

We bought all of Nikon's 8-16 x 40mm zoom binoculars. They had been retailing for $995. We sold all 105 for only $299 each – saving you $696.

This spring we bought all of Celestron's 8x and 10x Regal LX binoculars. Retail was $442, but we sold all 250 of them for $169.95 each, *less than half dealer cost* – saving you over 61%.

We bought all 400 of TeleVue's $155 4.8mm Nagler eyepieces. We sold them for $95 – saving you $60 on each.

We bought Meade's entire inventory of 360 ETX90RA 3.5" Maksutovs. They had been selling for $695, but we sold them for $349 – saving you almost 50%.

Last year, we bought 700 Meade Deep Space Imager CCD cameras. They had been $299, but we sold them for $99 – saving you $200 . . . a full two-thirds.

And we also bought 325 of Meade's DSI Pro CCD cameras. $399 retail, but we sold them for $129 – a $270 savings.

We recently bought all 220 of TeleVue's 15mm Panoptic eyepieces. We dropped the normal $210 retail to $159.95 and sold them all – saving you over $50 each.

250 of Celestron's C5+, 500 NexStar 80, 475 NexStar 114, hundreds of Meade black tube ETX-60s and 102mm achromats on LXD-500 mounts, and more . . . your savings go on and on.

Astronomics makes the quantity buys that save you big money. Always have, always will. And, if you are a *Cloudy Nights* member. you save even more. Here is your latest chance to save big . . .

And here's what Astronomics is doing for you today . . .

a 5" Meade ETX for $698 – *less than dealer cost.*

We bought Meade's entire inventory of 5" **Meade ETX-125PE** Premier Astro Edition go-to Maksutovs – a total of 620 scopes. We got them at such a good price that we can sell them to you for less than regular dealer cost. Savvy astronomers snapped up over 500 in the first two months, so you'd better take advantage of this special price while we still have a scope available for you.

Your Meade ETX-125PE has an adjustable height tripod with built-in equatorial wedge, red dot finder, 26mm Super Plössl eyepiece, *Level North Technology* for automatic sky alignment, 30,000+ object AutoStar go-to computer, a full-color deep space image on its optical tube, more.

Best of all, you save over $300!

TMB triplet apo refractors are in stock.

The 130mm f/7 **TMB-130** apochromatic triplet, left, is a *Hot Product for 2007.* Unlike other premium refractors with multiyear waiting lists, this big apo is available now.

The 13.5" long 92mm f/5.5 **TMB-92** triplet apo, right, fills the void left by the discontinued 90mm Astro-Physics Stowaway (a legendary scope that sells for up to $6000 on the used market). But a new TMB-92 is only $1999 and it's available now.

Both scopes have collimatable lens cells, FPL-53 ED glass, a genuine *FeatherTouch* dual-speed rotating rack and pinion focuser (a 3.5" drawtube model on the TMB-130, and a 2.7" on the TMB-92), case, and more.

A $100 rebate on the Celestron SkyScout.

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The multiple award-winning *Hot Product* **Celestron SkyScout** puts you on a first-name basis with the universe. This non-magnifying GPS-based hand-held personal planetarium leads you to and identifies *every* celestial object visible to your unaided eye. You can hear their stories through earbuds or the whole family can read them on a scrolling 5-line text and graphics display.

And now, through June 15, 2008, you'll get a $100 rebate check from Celestron when you buy the $399 SkyScout. That brings your final cost down to only $299!

Competitors? At $1195, the Astro-Tech 102ED has none.

No competitive refractor gives you as many standard features for $1195 as the **Astro-Tech AT102ED**.

You get a genuine *Feather Touch* dual-speed micro-focuser custom-made for the 102ED*; illuminated multiple reticle finder*; locking hard case*; dual hinged tube rings with separate 8" dovetail*; 102mm f/6.95 ED doublet optics; retractable dew shield with lock knob*; rotating Crayford focuser; 1.25" and 2" compression ring eyepiece holders; *2-year* warranty*; more.

Competitive scopes just can't compete.

*Features marked with asterisks are either optional or unavailable with some or all competitive refractors.

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Astro-Tech – the best buy in altazimuth mounts.

The $299 **Astro-Tech Voyager** altazimuth mount has a 20 pound payload capacity, worm drive manual slow motion controls, an adjustable height aluminum tripod, Vixen-style dovetail mount, and a price as much as 25% below competitive mounts with less payload capacity. It's clearly the new leader in altazimuth mount value.

Even better, buy *any* scope from Astronomics, and a Voyager is yours for only $249.

The best Celestron 8 cost $1295 in 1979. Today, an even better *go-to* Celestron is only $1399.

When we started business in '79, a Celestron C8 cost $1295 and was an incredible bargain. A state-of-the-art 1979 C8 would cost $3709.28 in today's inflated dollars – but wouldn't have the go-to computer, multicoatings, DC drive, or Plössl eyepiece of today's $1399 **Celestron NexStar 8 SE.**

But it *would* still have Celestron's superb Schmidt-Cassegrain optics. That's one important benefit for you that hasn't changed over the years.

If you think about it, Celestron prices have actually *deflated* since 1979. You get more scope, but effectively pay *less* money, since many of today's advanced features were unavailable at *any* price only a few years ago (like the *SkyAlign* go-to computer that makes astronomy as easy as 1-2-3, and the Starbright XLT multicoatings that give brighter images and higher contrast).

Is a **Celestron NexStar SE** a great value? *Absolutely!*

NexStar 4 SE, 4" Maksutov **$599**
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You don't have to enter your time or location or memorize a star chart to use a CPC either. Its built-in GPS system and a few anonymous lights in the sky are all you need.

Celestron CPC Schmidt-Cassegrains, with advanced Starbright XLT multicoatings, come with all the features you need to start go-to observing immediately.

8" **CPC800**, with XLT multicoatings **$1999**
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Great Astro-Tech eyepiece values from $39.95 to $99.95.

The new Astro-Tech eyepieces are good examples of the Astro-Tech philosophy of giving you "more performance for less money."

The **Astro-Tech Series 6** 1.25" eyepieces, above left, have wide 60° and 65° fields at only $39.95 each. Fully multicoated, with fold-down rubber eyecups, they are inexpensive enough to buy two at a time for binoviewer use.

Series 6 – 1.25", 60° field, 8 or 12mm ... **$39.95**
Series 6 – 1.25", 65° field, 17 or 20mm ... **39.95**

The **Astro-Tech Titan** 1.25" and 2" eyepieces (the 2" 38mm is to the left) all have wide 70° fields, twist-up rubber eyecups, good eye relief, and none is priced higher than $99.95.

Titan – 1.25", 70° field, 10 or 15mm .. **$59.95**
Titan – 1.25", 70° field, 20mm **69.95**
Titan – 2", 70° field, 26mm **79.95**
Titan – 2", 70° field, 32mm **89.95**
Titan – 2", 70° field, 38mm **99.95**

Are the Astro-Tech eyepieces great values? Does the sun rise in the east? The answer to both questions is yes!

"Ritchey-Chrétien-like" Meade Advanced Coma-Free performance starts at $1999.

Sky & Telescope said that Meade's original Advanced Coma-Free f/8 catadioptric "does indeed perform like a Ritchey-Chrétien." And *Astronomy* said it "delivers Ritchey-Chrétien-like performance at a fraction the cost."

Lower cost f/10 versions of those same flat-field Advanced Coma-Free optics are now available in **Meade LX90-ACF** GPS-based go-to scopes. They make "Ritchey-Chrétien-like" performance affordable for just about everyone.

Why pay thousands more for the flat field of a true Ritchey-Chrétien reflector optical tube only – and still have to pay for a mount to sit it on? Meade LX90-ACF catadioptrics with the latest "Ritchey-Chrétien-like" Advanced Coma-Free optics and a full go-to mount start at only $1999!

Here are the *freight-paid* LX90 prices:

8" LX90-ACF, Advanced Coma-Free **$1999**
10" LX90-ACF, Advanced Coma-Free **2699**
12" LX90-ACF, Advanced Coma-Free **3299**

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INSIDE pullout star charts
Is NASA on the right track with its search for life? p. 28
Astronomy
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The life and death of super suns
Wolf-Rayet stars are big, hot, and bright. They might solve mysteries of the universe's biggest blasts. p. 34
Get ready for this summer's total solar eclipse p. 66
Spend the night with a 30-inch scope and a really dark sky p. 62
AND MORE!
Did ancient astronomers build Stonehenge? p. 52
Find your way through the summer sky p. 70
Bob Berman on astronomy news breakthroughs p. 14

CFHT/JEAN-CHARLES CUILLANDRE/COELUM

ON THE COVER

28 Are we looking for life in the right places?

34 The life and death of super suns

66 Get ready for summer's total solar eclipse

62 Observing the way it was meant to be

52 Did ancient astronomers build Stonehenge?

70 Find your way through the summer sky

14 Bob Berman on astronomy news breakthroughs

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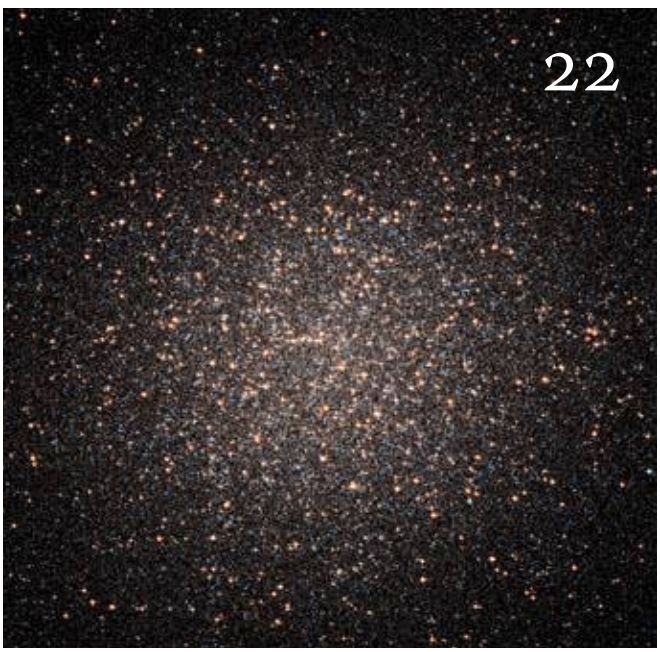

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8 **This month in *Astronomy***
Astronomy's Out-of-this-World Award 2008

10 **Beautiful universe**

12 **Letters**

13 **Web talk**

14 **Bob Berman's strange universe**
Marinating the news

16 **Glenn Chaple's observing basics**
Signposts of the sky

18 **Phil Harrington's binocular universe**
The Antares gang
WEB EXTRA: See more globular clusters and an observing calendar.

20 **Stephen James O'Meara's secret sky**
Vanishing acts, part 1
WEB EXTRA: Read an article that lists more objects in Lyra.

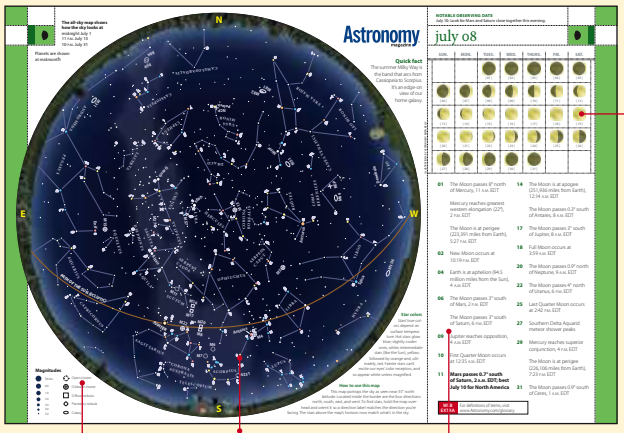
22 **Astro news**
Omega Centauri harbors a black hole, SELENE beams back lunar HDTV, Found: the solar system's oldest rock

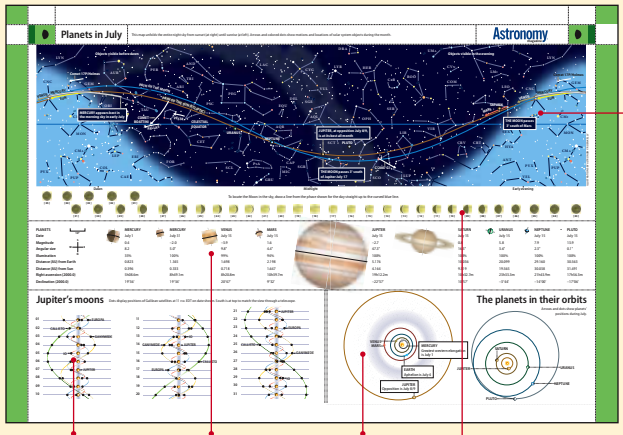
28 **Are we looking for life in the right places?**
For years, astrobiologists have looked for life on other worlds by "following the water." But could other substances hold the key? **DANIEL PENDICK**

34 COVER STORY

The life and death of super suns
Wolf-Rayet stars are big, hot, and bright, spewing gas and dust in all directions. Understanding how they die could help solve the mystery of what triggers the universe's biggest blasts. **ROBERT ZIMMERMAN**
WEB EXTRA: Listen to how astronomers found dust pinwheels.

EXCLUSIVE PULLOUT STAR CHARTS: Your guides for observing this month's night sky (p. 40)





40 **The sky this month**
Jupiter gleams, Mars glides past Saturn
MARTIN RATCLIFFE AND ALISTER LING

52 **Did ancient astronomers build Stonehenge?**
The driving force behind the building of Stonehenge was more theater than science. **DAN FALK**
WEB EXTRA: Dan Falk discusses his new book, *In Search of Time*.

58 **Ask Astro**
Nearest star could host exo-Earth
WEB EXTRA: Why do the Sun and Moon look bigger near the horizon?

62 **Observing the way it was meant to be**
What we saw through a 30-inch telescope under an inky black sky blew our minds. **MICHAEL E. BAKICH**

66 **Get ready for summer's total solar eclipse**
On August 1, the Moon will cover the Sun's face for a fortunate few. **MICHAEL E. BAKICH**

70 **Find your way through the summer sky**
Fill your summer nights exploring easy-to-find constellations, bright stars, and the Milky Way.
MICHAEL E. BAKICH
WEB EXTRA: Take a Meade Autostar tour of the listed objects.

72 **Advertiser index**

73 **New products**

78 **Reader gallery**

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BY DAVID J. EICHER

Astronomy's Out-of-this-World Award 2008

Two years ago, the editors of *Astronomy* magazine initiated a unique public service award for astronomy groups. Called the Out-of-this-World Award, the $2,500 cash prize will go to an educational group or civic organization that shows the greatest scope and creativity in popularizing astronomy.

The award recognizes an organization's ongoing efforts to involve its community in the science and/or hobby of astronomy. This year's application period is now open and entries must be postmarked by July 18, 2008.

It's easy to enter your group as a competitor for the award. Just submit an application form, which can be downloaded at www.Astronomy.com/award, and two essays: one describing your outreach project (consisting of 500 words), and another explaining how the monetary award would be used (250 words). I encourage you to submit photographs, media clippings, promotional flyers, and other relevant material. Outreach programs under consideration should be of a size and scope so that the $2,500 prize will allow demonstrable progress toward completion of a project or improvements: for example, purchase of a new telescope for public events, a laptop computer, marketing materials, signage for events, structural improvements for facilities, or technology upgrades.

Last year's winner was the Aldrich Astronomical Society of Worcester, Massachusetts. *Astronomy* editors chose Aldrich out of 41 entries from the United States and countries as distant as Romania. Aldrich runs a diverse group of outreach activities throughout surrounding communities. They used the award money to purchase equipment and books, and to develop demonstration toolkits. The group targeted a 6-inch reflecting telescope, two 10x50 and two 8x42 binoculars, two eyepieces with Moon filters, 75 star and planet locators, and a green laser pointer.

Aldrich programs include public observing sessions, planetarium shows, and mirror-grinding. Society members take their educational programs on the road, and give talks to community groups including the Boy Scouts and Girl Scouts of America. They visit libraries, local K-12 schools, colleges, and senior centers. They also offer more than 30 *PowerPoint* and slideshow presentations to the public on a variety of astronomical topics.

I invite your astronomy club or civic group to enter *Astronomy*'s 2008 Out-of-this-World Award competition. Entries will be judged by members of *Astronomy*'s editorial staff; the winner will be announced in October 2008. The award money must be used within 12 months of receipt. Please send entries to: *Astronomy* Out-of-this-World Award, 21027 Crossroads Circle, Waukesha, WI 53186. Good luck!

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 36, Number 7

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Revved-up star factory

On Earth and in the sky, massive collisions usually herald an object's demise. Yet in a few cases, such clashes lead to a remarkable rebirth. Witness the Antennae (NGC 4038/9) — a pair of merging galaxies in the constellation Corvus. Here, a cosmic smash-up is giving birth to billions of new stars. Most belong to clusters containing tens of thousands of members. They show up in this Hubble image as bright blue blobs. In many cases, these clusters still lie within the glowing pink clouds of hydrogen gas from which they formed. The larger, yellowish globes at upper left and lower right are the cores of the original galaxies. NASA/ESA/HUBBLE HERITAGE TEAM (STScI/AURA)

Exploring the cosmos at the speed of light

"Hubble gazes at red alien sunsets and star spots" (Astronews, April 2008) made me realize just how futile manned space travel really is. When you give it enough thought, we'll be lucky to get to Mars in the next 50 years. Then where do we go from there?

Traveling faster than light-speed is impossible, but in reality, we're already doing it! The Voyagers, Cassini, the Mars rovers, and the Hubble Space Telescope already deliver images of the cosmos to us at light-speed — detailed views unimaginable 40 years ago.

Now, we're discovering planets around other star systems. In the next 20 years, new instruments could conceivably get relatively close-up views of those other planets as well as analyze their atmospheres for life signs. That's true space exploration: bringing the cosmos to us! — **JAMES SAICHECK,** BANNING, CALIFORNIA

"No bucks, no Buck Rogers"

Thank you for "How historic observatories will survive" (April 2008), about efforts to maintain Yerkes Observatory. The Yerkes situation is not unique.

This year, the University of Toronto plans to sell the 73-year-old Dunlap Observatory, the largest telescope in Canada. The Science and Technology Facilities Council in the United Kingdom is threatening to withdraw from the giant Gemini and Jodrell Bank telescopes.

Astronomy funding today goes toward investigating the early universe, and older telescopes are less suited to this task. No bucks, no Buck Rogers. I hope there is still a place for suburban observatories like Yerkes and Dunlap. Very few readers will ever get the chance to visit, much less look through, the giant telescopes being built in South America. — **ERIC BRIGGS,** KHAN TELESCOPE CENTER, TORONTO, ONTARIO

MVP is AWOL

I was excited to hear that 2009 will be the official Year of Astronomy. This is a chance for millions of people to experience the universe and understand the immensity of the great cosmos.

Because Saturn's majestic rings will be invisible to backyard scopes in 2009, I'm worried the Year of Astronomy lost its most valuable player. Often, the view of Saturn's rings is the kiss of amazement that causes people to fall in love with astronomy. Let's all hope for something big in 2009, like a nearby supernova. — **JOSHUA D. WARREN,** MANITOU SPRINGS, COLORADO

Cheap fun, no side effects

I just came back from my local pharmacy, where I picked up my monthly prescription for Nexium. Each tablet costs $4.78. As a subscriber, my monthly issue of *Astronomy* costs $3.58 — less than one tablet of Nexium. What a bargain! — **JAY CRUTCHFIELD,** PRESCOTT, ARIZONA

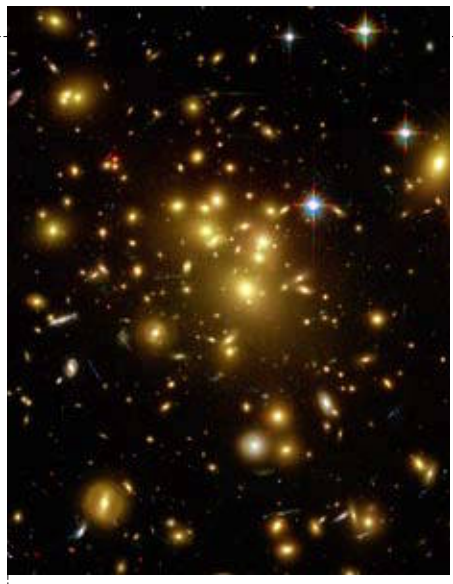
Solar filter confusion?

In "How to observe the Sun" (April 2008), author Michael Bakich says that you see fewer solar prominences through the narrower Hydrogen-alpha filter (0.5Å) than through the wider (1.0Å) filter. Prominences radiate over the entire H-alpha line width, so you should be able to see them all through the narrower filter. The only downside I know of for the narrower filter is the higher price. — **JAY M. PASACHOFF,** HOPKINS OBSERVATORY, WILLIAMS COLLEGE, WILLIAMSTOWN, MASSACHUSETTS

Because I was writing for beginning solar observers, perhaps my statement generalized too much without further explanation.

For the audience that story addressed — especially considering the small apertures typically used for visual observing (not astroimaging) — narrower structure and finer detail translates to "less visible." So, if we set up similar telescopes, one with a 0.5Å filter and the other sporting a 1.0Å filter, all but the most critical observers would notice more prominences through the 1.0Å filter. A camera, however, would record all prominences through both filters.

— **MICHAEL E. BAKICH,** SENIOR EDITOR



NASA/ESA/L. BRADLEY (JOHNS HOPKINS UNIVERSITY)/R. BOUWENS AND G. ILLINGWORTH (UC-SANTA CRUZ)/H. FORD (JOHNS HOPKINS UNIVERSITY)

THE HUBBLE SPACE TELESCOPE imaged this massive cluster of galaxies — a view of the universe accessible to anyone with an Internet connection.

Correction

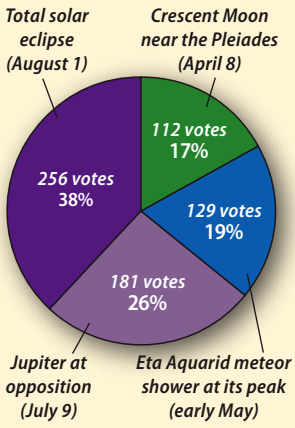
On page 33 of *100 Most Spectacular Sky Wonders*, Visible: North of latitude 68° N should read 68° S. — **ASTRONOMY EDITORS**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Webtalk

Online poll results

Which sky event are/were you most looking forward to observing?


Total solar eclipse (August 1)
Crescent Moon near the Pleiades (April 8)
112 votes 17%
129 votes 19%
181 votes 26%
256 votes 38%
Jupiter at opposition (July 9)
Eta Aquarid meteor shower at its peak (early May)

Total votes: 678

Join the fun! You'll find the weekly question on the lower right side of the home page.

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SEE DAVE EICHER'S FAVORITE DEEP-SKY OBJECTS (PARTS 1 AND 2)
Astronomy's editor shares nebulae, galaxies, and clusters he likes to observe.

July web extras

Go beyond the stories printed in this issue with these subscriber-only features. Monthly web extras bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

"The Antares gang" p. 18
See a brief binocular observing calendar for the rest of 2008.

"The life and death of super suns" p. 34
Astronomer John Monnier explains how astronomers found dust pinwheels.

UNIVERSITY OF CALIFORNIA, BERKELEY, SPACE SCIENCES LABORATORY/W.M. KECK OBSERVATORY

Dust pinwheel around Wolf-Rayet 104.

"Did ancient astronomers build Stonehenge?" p. 52
Dan Falk discusses his new book, *In Search of Time*.

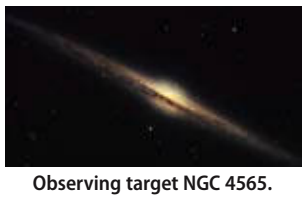
"Ask Astro" p. 58
Why do the Sun and the Moon appear bigger near the horizon?

This month's top blogs

Editors put their spin on current events in the staff blog. You can share your opinions on news headlines and popular culture, too.

1 **VISIT AN ASTRO-SOFTWARE GOLDMINE.** Astro Events Group of Ostend, Belgium, created a web archive filled with astronomy-related software. **BY FRANCIS REDDY**

2 **WHAT DO I LOOK AT NEXT?** Learn what to observe when you think you've seen everything the sky has to offer. **BY MICHAEL BAKICH**

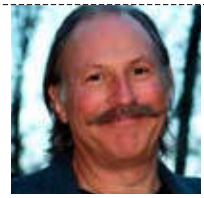


ADAM BLOCK/NOAO/AURA/NSF

Observing target NGC 4565.

3 **IN NEED OF SOME RESPECT.** Saturn's moon Rhea may finally be getting the attention it deserves. **BY RICHARD TALCOTT**

BY BOB BERMAN



Marinating the news

We all love astro-headlines: "Antimatter erupts from the galaxy's center," "Astronaut in diapers attacks her rival," "Planet Pluto gets canceled like a sitcom." For the past 35 years, my job for various publications has been to decide what news is exciting enough to share with readers.

Sometimes a discovery fizzles out, or it's just not very special. Remember cold fusion? Or the palindrome, "Rats live on no evil star?" Both never caught on. What's really needed is a pause to let it all sink in, to see if theories hold up. Well, we've now waited a decade — long enough to realize that near the end of the millennium three astonishing discoveries happened — bam, bam, bam — all at the same time. They shook the world.

We've discussed some of this before, but it's gotten more certain with time. The first involves particle entanglement. For decades, Einstein and others insisted that when bits of light or matter are born together, they go on their merry ways and live independent lives. If one flies to another galaxy, there's not even a postcard — its twin loses touch with it. This supports locality, the notion that objects can live independently from others, like teenagers and parents. (Yeah, right!). Otherwise, Einstein sneered, there'd have to be some kind of "spooky action at a distance."

But Einstein was wrong and spooky was right. In 1997, Nicolas Gisin of Geneva, Switzerland, proved it with a brilliant experiment. He built on the work of John Bell, who'd said previously that even solid objects have a wave nature whose existence is blurry, iffy, and probabilistic. Only when observed or interfered with does this wave function collapse, and only then is the particle really in a particular location. Until then, it inhabits a nether world where anything's possible.

Gisin's experiment showed that when one object's wave function collapses, its twin instantly knows this and suddenly materializes in a matching, complementary way, even if they're separated by the width of the galaxy. Gisin used entangled photons 7 miles apart. The experiment, since replicated with heavy, solid objects, proves that bits of light or matter gain this knowledge infinitely faster than lightspeed, and — shazam! — suddenly assume new identities.

Distance is irrelevant. In fact, it suggests space is not even real. Since the whole universe was born together, this experiment also implies everything may be interconnected. Sounds like Woodstock, man.

SINCE THE WHOLE universe was born together, this experiment also implies that everything may be interconnected. Sounds like Woodstock, man.

Discovery number two involved Einstein again. He and fellow physicist Satyendra Nath Bose pondered quantum mechanics and realized that, at extremely cold temperatures, atoms might blur into each other. Their wave natures would clump together like shredded wheat, making them lose their individuality in a new state of existence.

The hunt for this theoretical fifth state of matter — with solid, liquid, gas, and plasma — came to an end in 1995, when physicists finally chilled atoms to a few billionths of a degree above absolute zero. The technique involved stages of cooling: Converging lasers produced an optical molasses, slowing down the atoms until evaporative cooling and ever-changing magnetic confinement finally let the material come to a standstill, at –459.67° Fahrenheit (–273.15° Celsius).

Sure enough, there it was, the fabled Bose-Einstein condensate, which has no natural existence anywhere in the universe. The condensate was weirder than the drawer in which you keep your underwear. These few million atoms turned into a kind of ultra-fragile superball. Light beamed into it screeches almost to a halt, like Wile E. Coyote just after he runs off a cliff. Frozen light. It crept along at just 38 mph (61 km/h). You'd honk at it annoyingly if you passed it on the highway. Later this century, technology will exploit this new state of matter to make gadgets beyond our wildest dreams.

The final discovery came in 1998, when astronomers found we'd been wrong for 68 years. The universe's expansion isn't slowing down after all. Instead, when the cosmos was half its present age, it started expanding at a quicker rate. Now it's gaining speed every second, with trillions of cubic light-years of new empty space depressing real estate values everywhere. Some bizarre antigravity force must be anarchically making the universe explode. This repulsive entity, quickly named dark energy, is still mysterious.

It takes a lot of power to blow apart a universe that weighs 1-followed-by-50-zeros tons, so dark energy has to be the biggest component of the cosmos. The big enchilada. The universe is three-quarters dark energy — whatever that is. And if it doesn't exist, which still is possible, then gravity itself must be very different from what we've always believed. Either way, everything changes.

Three bombshells in a few years. That was a decade ago. Nothing comparable has happened since.

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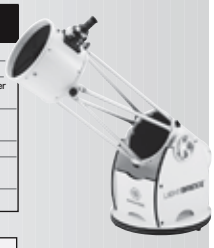

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BY GLENN CHAPLE

Signposts of the sky

Take a look at the image in the center of this page. Which constellation do these stars belong to? I'll give you a hint: They currently are visible high in the northern sky. ☾ If you answered "the Big Dipper," you're wrong! The photo does indeed depict the Big Dipper, but the question was "Which constellation?" The correct answer is Ursa Major the Great Bear.

The Big Dipper is the most recognizable asterism — a distinct pattern of stars that isn't a true constellation. Like the Big Dipper, the Keystone of Hercules and Sagittarius' Teapot are asterisms that are part of much larger constellations. The Summer Triangle, on the other hand, encompasses more than one constellation. It's defined by the stars Vega in Lyra, Altair in Aquila, and Deneb in Cygnus.

THIS WELL-KNOWN PATTERN is recognized worldwide. The French know it as the Casserole, while the Irish call it the Plough. BILL AND SALLY FLETCHER

Asterisms serve a valuable purpose. Like traditional constellations, they divide the night sky into recognizable shapes. Novice skygazers use asterisms as guideposts. They also delight children who enjoy looking up at the sky and finding Cassiopeia's "W" (or "M") or a backward question mark in Leo.

Not all asterisms are visible to the naked eye. Some "mini-asterisms" present worthy targets for binoculars and telescopes — every bit as pleasing to the eye as Messier or NGC objects. Check out the Coathanger in Vulpecula. Also known as Brocchi's Cluster and Collinder 399, the Coathanger is a striking sight through binoculars or low-power, rich-field telescopes. My eye catches a remarkably straight east-west row of a half-dozen 6th- and 7th-magnitude stars outlining the base. Four more stars loop out from the center to form the hook.

Here's an easy way to locate the asterism: Train your binoculars or finder scope on Altair (Alpha [α] Aquilae). It's the middle of three bright stars that point to the Coathanger. From Beta (β) Aquilae at the southeast end of the row, trace a line through Altair and Gamma (γ) Aquilae. Continue twice the length of the Altair row, and you'll arrive at the Coathanger.

If I've piqued your interest in these signposts and you'd like to see more, visit the Saguaro Astronomy Club's web site at www.saguaroastro.org. You'll find pertinent data and descriptions of 110 stellar shapes. A brief gallery of asterisms can be found at www.deep-sky.co.uk/asterisms.htm. And don't forget that *Astronomy* Contributing Editor Phil Harrington frequently mentions signposts in his column, "Binocular Universe." Check out the Garden Trowel in Scorpius, which Phil describes this month.

Sensible housing

Bob Winder of Niagara Falls, New York, recently asked me this question: "Without a backyard observatory, where should I store my telescope when not in use?" Winder keeps his large Dobsonian-mounted instrument in his car. Bob wanted the scope to be ready for instant transport to his astronomy club's dark-sky site.

Such a practice certainly would prevent backache, but could lead to heartbreak if the car is parked out in the open, where the Sun could damage the scope. On a midsummer day, the internal temperature of a locked car with windows rolled up can exceed 140° Fahrenheit (60° Celsius), enough to compromise a telescope's optics and any electronics it uses.

The first consideration when looking for a place to store your telescope is security. Keep it in a location safe from vandals or thieves. Next is protection from the elements: rain, sleet, snow, or extreme temperatures. Finally, consider temperature equilibrium, which means keeping your telescope where the temperature is close to what you'll find outside.

I house and lock my telescopes in a well-ventilated storage shed located in a shady part of the backyard. When it's time to observe, the instrument I select is at equilibrium with the night air — no blurry image due to expanding or shrinking optics or air currents in the tube. I'm ready to explore the Moon, planets, a nebula, or asterism.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: Do you know what *Georgium Sidus* is? Clear skies!

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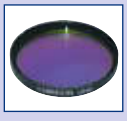

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BY PHIL HARRINGTON

The Antares gang

This month, we have two beacons in the southern sky: Jupiter and **Antares** (Alpha [α] Scorpii). Jupiter is just passing through, but Antares shines brightly in our summer sky every year, like a lighthouse beacon in an ocean of fainter stars. Even though it lies more than 600

light-years away, Antares is one of the sky's brightest stars because of its immense size. Antares translates as "rival of Mars," owing to the star's similar appearance to the Red Planet, and to its proximity to the ecliptic. The red supergiant is nearing the end of its life. The hydrogen-to-helium fusion process powering it since birth has run its course, causing the star to swell to enormous proportions.

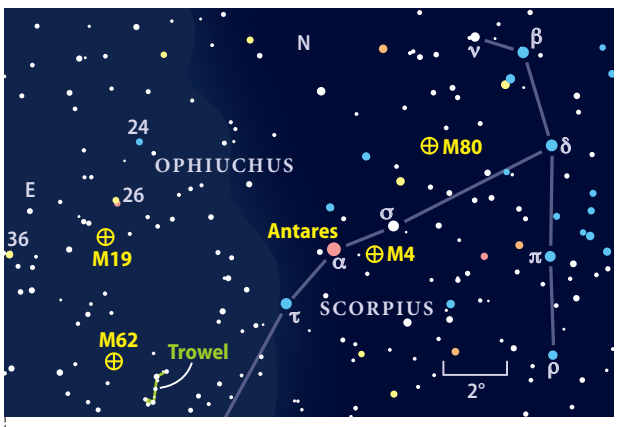
Antares is so large that, if it were put in the Sun's place, its outer edge would extend nearly to the orbit of Mars. Antares is a fun object to observe through binoculars. Its deep ruddy color, rivaling that of Betelgeuse in winter's Orion, is readily apparent. Often, Antares appears to flash through many other colors as well because of interference from our atmosphere. The star's position, low in most of our skies, accentuates this sparkling effect.

Immersed in the glow of the Milky Way, Antares makes a wonderful jumping-off point to search for many hidden treasures. Let's begin with globular cluster **M4** (NGC 6121). You don't need to move a muscle to see it when you're staring at Antares — it's just a half degree to the west. Look for a dim, round glow that resembles a distant cotton ball.

At 7,200 light years away, M4 is relatively close to Earth for a globular cluster. This makes it appear bigger than most, and easy to identify through 6x binoculars. But because M4 is quite loosely structured, its lack of a condensed center can confound observers who must battle light pollution.

Scorpius also houses a second Messier globular cluster that proves more challenging through binoculars: **M80** (NGC 6093). This cluster's small, dim disk rests halfway between Antares and Beta (β) Scorpii. Although its star-like core is typical of the breed, M80 is tiny compared to M4, so identifying it from surrounding stars can be difficult.

Now, place Antares at the western edge of the field and look on the opposite side for a close-set pair of 5th-magnitude stars, lying across the invisible border in Ophiuchus. The globular cluster **M19** (NGC 6273) lies just a degree to their south. Looking a little larger and slightly brighter than M80, M19 should reveal itself as a fuzzy "star" through 7x binoculars.



ASTERISMS PRESENT CHALLENGES for beginning observers. Find the Garden Trowel after you survey Antares and the clusters featured. *ASTRONOMY:* ROEN KELLY

While viewing M19 through 10x50 binoculars, Jim Elliott of Lee County, North Carolina, observed an unusual arc of three optical double stars curving around M19 to the northeast. I call this assembly of stars, which includes 24, 26, and 36 Ophiuchi and SAO 184892, 185020, and 185033, the Dish σ' Doubles, because they remind me of a satellite dish, with M19 at the focus.

M62 (NGC 6266) sounds like it should be a twin of M19. But when you look for it, about half a field to the south, it is more difficult to see. From the Naylor Observatory outside of Harrisburg, Pennsylvania, Astronomy.com Forums moderator David Mitsky described M62 as "a small, featureless fuzzy" through his 8x42 binoculars. "However, my 15x70 binoculars revealed a brighter, stellar core."

One of my favorite summer asterisms lies just 1.5° southwest of M62. If you're a gardener, you'll recognize it as a celestial garden trowel. Give observer John Davis of Amherst, Massachusetts, credit for digging up this one. Davis draws the **Garden Trowel** from three 7th-magnitude stars set in a south-pointing triangle and a trail of three 6th- and 7th-magnitude stars meandering off to the north. Although most of the Trowel's stars are white, two or three shine with a subtle golden glint.

No fewer than 22 other globular clusters lie within Ophiuchus, more than any other constellation, except Sagittarius.

Next month, we'll survey clusters and nebulae found near the Sagittarius Star Cloud. Till then, remember that two eyes are better than one.

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BY STEPHEN JAMES O'MEARA

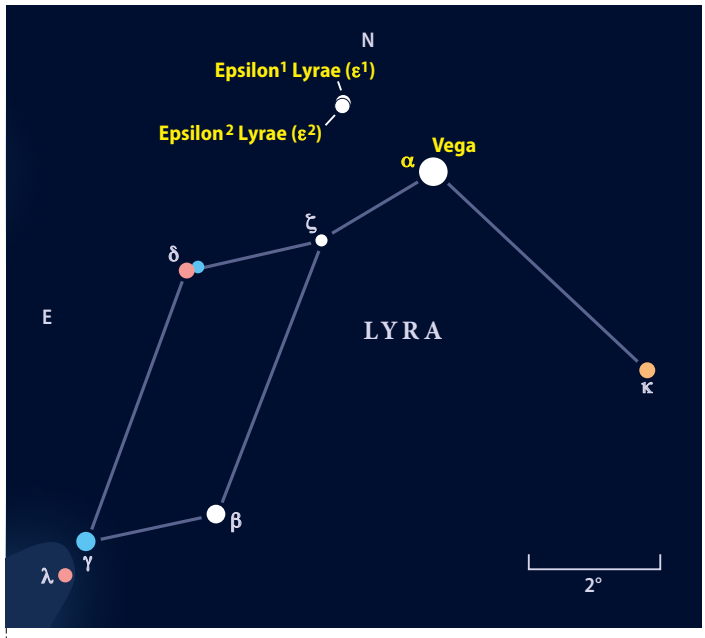
Vanishing acts, part 1

In 1918, Harry Houdini performed his greatest feat when he made Jennie the Elephant vanish in the middle of New York's Hippodrome Theater. But that trick is peanuts compared to your natural ability to make stars vanish from the sky. Yes, the magic is in you. All you need is a clear night, transparent skies, and the ability to look straight at a star without averting your gaze. It's trickier than you think.

To see faint objects, stargazers have learned to avert their gaze. Doing so places a star's image on the eye's night-sensitive rod cells, which line the periphery of the retina. Using averted vision at night is a basic human instinct. We rely on it to detect shape and movement in low-light situations. Looking at anything other than the Moon and the bright planets with a direct gaze after sunset is almost taboo. Averted vision is one of the important principles of visual perception in amateur astronomy.

The problem with using direct vision to see faint starlight is that it focuses light on the eye's central fovea, which is packed with day-sensitive cone cells. Although our cones do not stop working at night, their ability to perform is affected by an object's apparent brightness — visual acuity diminishes as brightness decreases.

Yet, despite its restrictions, foveal vision can play an important role in our ability to see fine details in the night sky. You just need to know the limits of direct vision at night.



LYRA'S BRILLIANT VEGA provides your first challenge in this month's magic act. This chart shows the constellation's stars that are brighter than magnitude 5. *ASTRONOMY:* ROEN KELLY

Now you see it ... now you don't

On the next clear night, go outside and wait at least 15 to 20 minutes for your eyes to adapt to the dark. Next, fix your gaze directly at blue-white Vega (Alpha [α] Lyrae), which shines at magnitude 0. You'll have to fight the urge to avert your gaze. The difficulty is enhanced because your eyes also make involuntary movements — rapid little jerks called saccades — to ensure that the image continuously sweeps across receptor cells.

With practice, you can keep the eye movements to within 30' (the Full Moon's apparent diameter) of the star, which is the precision you need. Doing so places Vega within the foveala, the central portion of the fovea where only cone photoreceptors, but virtually no rods, are present.

The first thing you'll notice is that while Vega may dim with a direct gaze, it will not disappear — proof that cone cells do work at night. Now use the star chart on this page and repeat the exercise while moving down the magnitude scale, testing fainter and fainter stars.

Observers with good eyes and normal night vision probably will find that stars of magnitude 5 will vanish immediately with a direct gaze. Stars hovering around magnitude 4.5 may vanish after a few seconds of intense staring.

You want to find the faintest star possible that will not disappear. Be sure to repeat this exercise under different sky conditions and record the results. The limits listed are only a general guideline. Results may differ from person to person, night to night, and location to location.

Last January, I tested my foveal vision under the light of a Full Moon and very transparent skies at an altitude of nearly 5,000 feet (1,524 meters). I selected stars in regions that covered areas in the northern and southern skies at similar altitudes. The results? I consistently kept stars of magnitude 3.8 and 4.1 in my central fovea without having them vanish. Stars ranging between magnitudes 4.2 and 4.6 vanished from view after a few seconds of intense staring.

Under dark, moonless skies from the same location, stars of magnitude 4.2 remained in view. Those of magnitude 4.5 hovered neared the limit of foveal vision. A magnitude 4.8 star remained visible for only

EPSILON LYRAE, also known as the Double Double, separates well in this image made with a 3.15-inch scope. Try separating the combined light of Epsilon[1] from that of Epsilon[2]. DAMIAN PEACH

THIS AURORA'S glowing curtain fails to block Vega in a photograph taken October 1, 2001, from Sainte-Foy, Quebec. DOMINIC CANTIN

a few seconds before winking out. Fainter stars disappeared almost immediately.

When we use averted vision at night to see faint stars, we sacrifice resolution. The preponderance of cone cells in the fovea, and the lack of retinal blood vessels which can interfere with the passage of incoming light, give the eye its resolving power, or its ability to detect fine detail. As long as an object is bright enough for the fovea to see it, we should try using direct vision if our goal is to see detail.

The region of greatest visual acuity lies in the fovea's central 20' to 30' — in the foveala. Stare directly and intently at any letter in this sentence. You should be able to resolve it clearly. But notice that if you're careful not to redirect your eyes, the letters to either side of it are less distinct. Resolution disintegrates dramatically the farther an image is from the foveala.

Seeing double

How does this knowledge impact your observing? Consider one of the most fun yet extreme visual challenges under the summer night sky: Splitting the naked-eye double star Epsilon (ε) Lyrae.

At a glance, Epsilon Lyrae shines as a single star of magnitude 3.9. But that single star is really the combined light of two stars: Epsilon[1] Lyrae, which shines at magnitude 4.7, and Epsilon[2] Lyrae, which shines at magnitude 4.6. The stars are separated by 3.5', which is within the grasp of sharp-eyed observers. The sharpest eyes can resolve to about 3'.

VEGA, DENEB, AND ALTAIR form the asterism the Summer Triangle. Observing from a dark-sky site, make sure you take in this group and the Great Rift after you attempt to make Vega "disappear." GIANNI TUMINO

Using direct vision, I can see Epsilon Lyrae without the star disappearing. I also can see with direct vision stars to magnitude 4.6 — if only for a few seconds under full moonlight. That means splitting Epsilon Lyrae is a reasonable and worthy challenge for me. But I'm interested in knowing the limits of your direct vision.

If you successfully split Epsilon Lyrae — under bright or dark skies — I'd like to hear your story. E-mail reports, with details about your age, vision, observing experience, and where you stargaze from, to someara@interpac.net.

WEB EXTRA Read an article from *Deep Sky* magazine that lists more objects in Lyra at www.Astronomy.com/toc.

Cassini 2010 On April 15, NASA announced its approval of a 2-year mission extension for the Cassini spacecraft, now in orbit around Saturn.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

Astronews

BLACK HEART. Astronomers say Omega Centauri, an object classified as a globular cluster, hosts a central black hole. This suggests the cluster, which lies 17,000 light-years away, may be a dwarf galaxy's core. NASA/ESA/HUBBLE HERITAGE TEAM (STScI/AURA)

23 **WMAP finds cosmic neutrino background**

24 **Amateurs see fireballs from satellite kill**

25 **Solar system's oldest asteroids found**

26 **Cassini "tastes" Enceladus plumes**

Omega Centauri harbors a black hole

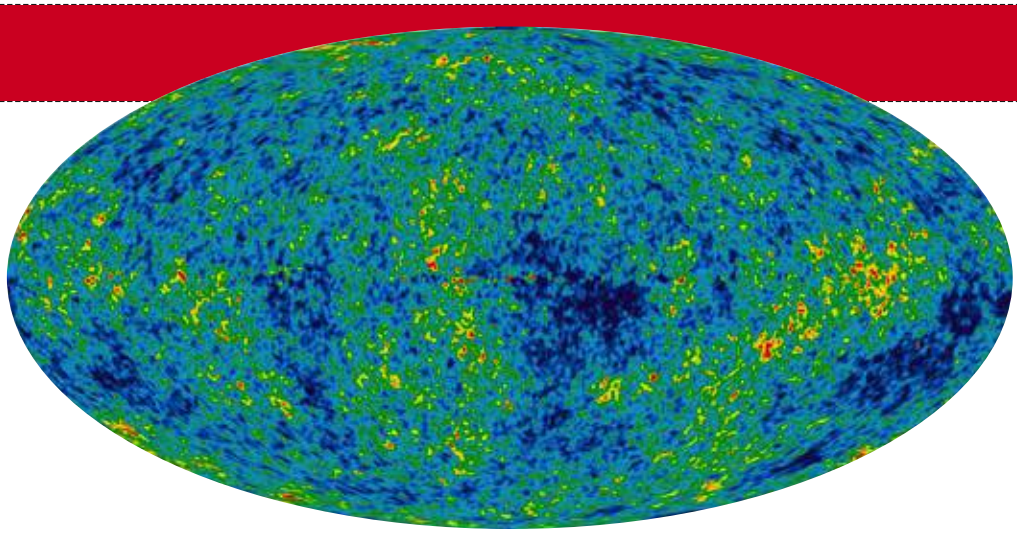
Our galaxy's largest and brightest globular star cluster, Omega Centauri, is a well-known astronomical puzzle. A study using data from the Hubble Space Telescope and the Gemini South Observatory in Chile shows why: the cluster harbors a medium-sized black hole.

Like other globular clusters, Omega Centauri is a ball of up to a million suns that orbits in our galaxy's outskirts. It rotates faster and hosts more stellar generations than typical globular clusters. With 10 times the mass of other Milky Way globulars, Omega Centauri stands out.

Astronomers wondered if Omega Centauri is the core of a dwarf galaxy stripped of its outer stars by tides from the Milky Way. The presence of a central black hole backs up this notion.

Eva Noyola at the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, led the discovery team. The researchers measured the speeds and brightnesses of stars in the cluster's center. Its total estimated mass is too low to account for the speeds of its central stars. The stellar motions work out, they say, if the stars swirl around a black hole weighing some 40,000 Suns.

Omega Centauri joins G1, a giant globular cluster orbiting the Andromeda Galaxy (M31), as the second observation of an intermediate-mass black hole. Noyola says the finding provides evidence that black holes come in all sizes. — **FRANCIS REDDY**



COSMIC BACKGROUND. WMAP data show fine temperature fluctuations in the cosmic microwave background radiation. The latest data release suggests the existence of a neutrino background tied to an earlier epoch of cosmic history. NASA/WMAP SCIENCE TEAM

WMAP finds cosmic neutrino background

Since 2003, the Wilkinson Microwave Anisotropy Probe (WMAP) has refined our knowledge of the universe's first moments and its current state. In March, scientists presented the mission's 5-year data release. The key finding: A sea of neutrinos permeates the universe.

These particles — which are almost weightless and race around at nearly the speed of light — once made up a larger fraction of the cosmos than they do today. The microwaves WMAP observes, released when the universe was 380,000 years old, show neutrinos composed 10 percent of the universe, atoms 12 percent, photons 15 percent, and dark matter 63 percent. Dark energy, a force that appears to be accelerating the universe's expansion, was negligible.

In comparison, the universe today comprises 4.6 percent atoms, 23 percent dark matter, and 72 percent dark energy. Neutrinos make up just 1 percent of the cosmic contents. The composition varies as the universe expands, but the energy density of photons and neutrinos decreases faster than that of ordinary matter.

The new data also show the universe's first stars, which turned on about 400 million years after the Big Bang, took a half-billion years to create a thin, microwave-scattering fog of free electrons. **— RICHARD TALCOTT**

Orion capsule prepared for short test flights

In March, NASA delivered a full-size structural model of the new Orion spacecraft to its Dryden Flight Research Center at Edwards Air Force Base, California. Before year's end, the instrumented capsule mockup will fly, if only briefly.

Unmanned tests at the U.S. Army's White Sands Missile Range in New Mexico will simulate a launch pad emergency. The goal is to verify that a new launch abort system can blast astronauts to safety.

During this series of launch pad abort tests, the escape system's rocket motor will fire for several seconds and lift the mockup about 1 mile (1.6 kilometers) high and nearly as far downrange. The escape system then will detach, and three 116-foot-wide (35 meters) parachutes will deploy. The chutes will bring the capsule to a soft desert landing.

NASA

OUT TO LAUNCH. This mockup of NASA's Orion crew module soon will fly in launch abort tests.

"These flight tests will either confirm that our system works or help us identify and correct any defects that surface," says Greg Stover, manager of the Orion Launch Abort System Project Office in Langley, Virginia. In 2009, higher-altitude tests will begin at NASA's Kennedy Space Center in Florida. **— F. R.**

QUICK TAKES

007 VISITS THE VLT
The residence at the European Southern Observatory's Very Large Telescope in Chile plays the villain's lair in *Quantum of Solace*, James Bond's latest movie adventure.

MOON-SHOT MEMORIAM
Celestis, the Houston-based firm specializing in sending the ashes of departed ones on suborbital flights, has announced a service to send remains to the Moon.

NO CREW, NO PROBLEM
U.S. scientists will use robotic aircraft to explore hurricanes this season. The vehicles will fly into the storms at altitudes considered too risky for crewed aircraft.

LASER POWER
The University of Texas in Austin now boasts the Texas Petawatt Laser, the world's most powerful.

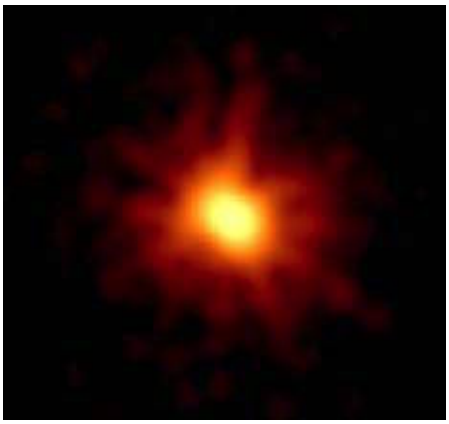
KOREAN SEES SPACE
On April 7, Yi So-yeon, a 29-year-old South Korean bioengineer, became the youngest woman and the first Korean ever to fly in space. A Russian Soyuz carried her to the International Space Station.

SHAKY START
On April 3, NASA engineers announced that violent shaking in the new Ares I rocket was a manageable problem.

RADS TO WATTS
Scientists at LAVM LLC in Los Alamos, New Mexico, are studying materials that convert radiation directly into electricity. This could be a boon to energy-starved probes working beyond Mars.

STERN LEAVES NASA
On March 26, planetary scientist S. Alan Stern, who headed NASA's Science Mission Directorate, resigned from the U.S. space agency.

BAD VIBES
Solar storms and gravitational tugs from the Sun and Moon could give passengers on space elevators a bumpy ride by making the elevator cable wobble, says Czech scientist Lubos Perek.



NASA/SWIFT/STEFAN IMMLER, ET AL.

SQUINT. NASA's Swift spacecraft imaged GRB 080319B's extremely luminous afterglow in X-rays. The gamma-ray burst sported the brightest afterglow ever seen.

"Whopper" GRB blazes to naked-eye brightness

At 2:12 A.M. EDT March 19, NASA's Swift satellite alerted astronomers to a gamma-ray burst in the constellation Boötes. The massive explosion occurred 7.5 billion light-years away — yet the blast's optical afterglow reached naked-eye brightness. The object was as bright as 10 million galaxies for nearly a minute.

"No other known object or type of explosion could be seen by the naked eye at such an immense distance," says Stephen Holland, a Swift science team member at NASA's Goddard Space Flight Center in Maryland. It was the most distant object ever to become so bright.

"This burst was a whopper," says Neil Gehrels, Swift's lead researcher at Goddard. "It blows away every gamma ray burst we've seen so far."

Gamma-ray bursts occur when massive stars run out of nuclear fuel and collapse to form black holes or neutron stars. High-energy jets of matter rip through the star's collapsing layers and beam a narrow cone of gamma rays into space.

Astronomers don't yet know why GRB 080319B and its afterglow were so bright. Factors like the mass, spin, or magnetic field of the collapsing star or properties of the jet may play a role. Alternatively, the jet's axis may have been unusually well-directed at Earth. **— F. R.**

Amateurs see fireballs from U.S. satellite kill

Observing unique time-critical sky events always takes a little luck, especially because of hit-or-miss weather conditions. On February 20, a group of skywatchers at Prince Georges Astronomical Observatory in British Columbia took the chance that a break in the clouds would let them glimpse the evening's total lunar eclipse then in progress. When the clouds briefly parted, the astronomers considered themselves fortunate.

But their luck was more extraordinary than they first realized. That hole in the clouds made these skywatchers the only North American eyewitnesses to the demise of the American spy satellite USA-193.

Only minutes before, as the spacecraft raced north of Maui, a head-on impact with a missile launched by the *USS Lake Erie* had smashed the 8-ton derelict. The reason for the strike was the satellite's half-ton cargo of toxic hydrazine fuel, which dispersed harmlessly into space. Thousands of small fragments scattered in all directions. At 7:43 P.M., many of the pieces hit the atmosphere directly over the eclipse observers.

Because the satellite exploded, its fragments followed random trajectories. Some pieces were flung forward into higher orbits, where a few could survive for several months. Others were flung off to the side, leading to a gently zig-zagging path that quickly decayed due to atmospheric drag. But many pieces were thrown downward along a track that passed over the Canadian skywatchers.

According to eyewitness Brian Battersby, observers spotted many simultaneous fireballs moving generally southwest to northeast. "One was especially bright and long-lasting," he reported in an e-mail, adding that he recalled "about six bright trails and 15 fainter ones."

The grouping of these man-made meteors differed from natural ones. "The debris trails seemed to come in 'waves,' with the first … being brighter than the debris that followed behind it," Battersby explained.

U.S. NAVY

POT SHOT. On February 20, the guided-missile cruiser *USS Lake Erie* launched a tactical missile to take down an errant satellite. *Inset:* The missile's payload turned USA-193 into a cloud of debris 153 miles (246 km) over the Pacific Ocean.

"The trails seemed to be in a fan shape, with the trails being wider apart in the northeast than they were in the southwest."

Unlike a natural meteor shower, where trails originate from a single steady point on the celestial sphere, the debris radiant was the disintegrated satellite's center of mass. That point was traversing the Canadian sky at about 2° each second. The fast-moving "shower" radiant explains the unusual pattern seen by observers.

Bonnie Bird of the Royal Astronomy Society of Canada relayed Battersby's report and searched for any other observers located far enough west to have seen the satellite's fireballs. But elsewhere in western Canada, the cloud cover had been nearly unbroken. Bird found no other witnesses.

The 30-odd skywatchers in Battersby's group defied the meteorological odds and were rewarded with the sky show of a lifetime: a man-made meteor storm no other humans had ever seen — or are likely to see for many years. These lucky observers, the envy of every other amateur astronomer and satellite watcher on the planet, will just have to inspire others to keep looking up. **— JAMES OBERG**

W. M. KECK OBSERVATORY ARTWORK

ANCIENT. **Calcium and aluminum coat the solar system's oldest asteroids.**

Found: the solar system's oldest rocks

A team of scientists led by the University of Maryland's Jessica Sunshine has found three of the solar system's most ancient asteroids. The space rocks, which formed some 4.55 billion years ago as the planetary system took shape, are older than any meteorite found on Earth and remain relatively unchanged.

The team determined the asteroids' ages using visible and infrared data collected from telescopes on Hawaii's Mauna Kea. Scientists believe calcium and aluminum were among the first elements to condense from the young solar system's swirling gas disk. So, the older the asteroid, the more calcium and aluminum it should contain.

The team's observations indicate asteroids 387 Aquitania, 980 Anacostia, and 234 Barbara contain up to 3 times as much calcium and aluminum as the oldest known meteorites.

"We have identified asteroids that are not represented in our meteorite collection and which date from the earliest periods of our solar system," Sunshine says. These rocks are prime candidates for future space missions that could collect and return samples to Earth, providing a more detailed picture of the solar system's first few million years.

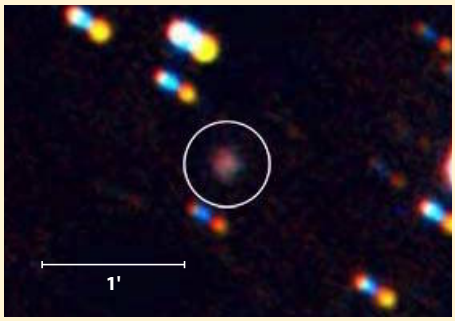
The report appeared March 20 at *Science* Express, the web site for the journal *Science*. — **MEGAN McCHAIN**

Comet Hale-Bopp still going strong

Eleven years after its 1997 race around the Sun, Comet Hale-Bopp (C/1995 O1) still hasn't settled down. Now nearly 2.4 billion miles (3.8 billion km) away, Hale-Bopp holds the record for the most distant cometary activity astronomers have ever witnessed.

A team led by Gy. M. Szabo at the University of Szeged, Hungary, observed the comet in October 2007 using the 2.3-meter Australian National University telescope at Siding Spring Observatory. The magnitude 20.4 comet showed a diffuse, slightly elongated coma more than 100,000 miles (160,000 km) across.

Carbon monoxide is driving Hale-Bopp's activity, the scientists say in a paper submitted to *Astrophysical Journal Letters*. The ice can turn to a gas (sublimate) even at large distances from the Sun. They suggest that further observations of Hale-Bopp using 8-meter-class telescopes will help astronomers further understand this record-breaking comet. — **F. R.**



GY. M. SZABO ET AL./ANU

FUZZBALL. **Hale-Bopp is beyond Neptune, but its carbon-monoxide ice is still sublimating to create an enormous coma.**

BRIEFCASE

New space molecule

Researchers from the Max Planck Institute for Radio Astronomy in Bonn, Germany, have detected the organic molecule amino acetonitrile (NH_2CH_2CN). The complex molecule turned up in the Large Molecule Heimat, a hot, dense gas cloud near our galaxy's center. Scientists think the molecule is a direct precursor to the amino acid glycine. — **R. T.**

Wee black hole

Nikolai Shaposhnikov of NASA's Goddard Space Flight Center and his colleagues have found a black hole weighing just 3.8 times the Sun's mass. The 15-mile-diameter (25 km) object forms half of the binary system XTE J1650–500 in the southern constellation Ara. This tiny black hole beats the previous record holder, which tipped the scales at 6.3 solar masses. — **R. T.**

Watery Moon

A new analysis of low-titanium lunar glass returned by Apollo 15 astronauts suggests the Moon isn't totally devoid of indigenous water. A team led by Alberto Saal at Brown University concludes that the Moon is not uniformly depleted in highly volatile elements, like water. — **F. R.**

25 years ago in *Astronomy*

July 1983

When David Darling wrote "Quest for black holes" for the July 1983 issue of *Astronomy*, astronomers were searching for evidence that black holes existed. If these invisible objects really existed in our universe, how could we find them?

"We must look for their effect on objects that can be seen," Darling wrote. Even though black holes can't be observed directly, scientists have confirmed at least 19 in the Milky Way, including a supermassive black hole in the center. Stellar-mass black holes form when stars die. Supermassive black holes weighing millions to billions of Suns originated when galaxies were young, closer together, and collided frequently.

July 1998

10 years ago in *Astronomy*

When Galileo viewed Saturn's rings in 1610, the poor optics of his telescope led him to believe the rings made Saturn a triple system: The planet resided in the center, and the rings appeared as two smaller bodies on either side. In 1659, Christian Huygens realized that what Galileo saw as small bodies actually were rings.

Astronomers now know that Saturn isn't the only body in our solar system with rings. Rings of various sizes and compositions swirl around Jupiter, Uranus, and Neptune, and possibly Saturn's moon Rhea. In July 1998, *Astronomy* addressed the subject in "Ruling the rings" by Neil F. Comins. He discussed planetary rings and what they can tell us about our solar system. — **M. M.**

Mini ship On March 26, California-based Xcor Aerospace introduced its Lynx, a sleek, two-seat, suborbital spacecraft. The company expects the Lynx to be ready for test flights by 2010.

SELENE beams back lunar HDTV

Japan's SELENE spacecraft reached the Moon last October and began routine science observations in December. In the months since, the orbiting satellite has measured the elemental abundance and mineral composition of the lunar crust, the topography and geological structure of the Moon's surface, and the space environment surrounding the Moon.

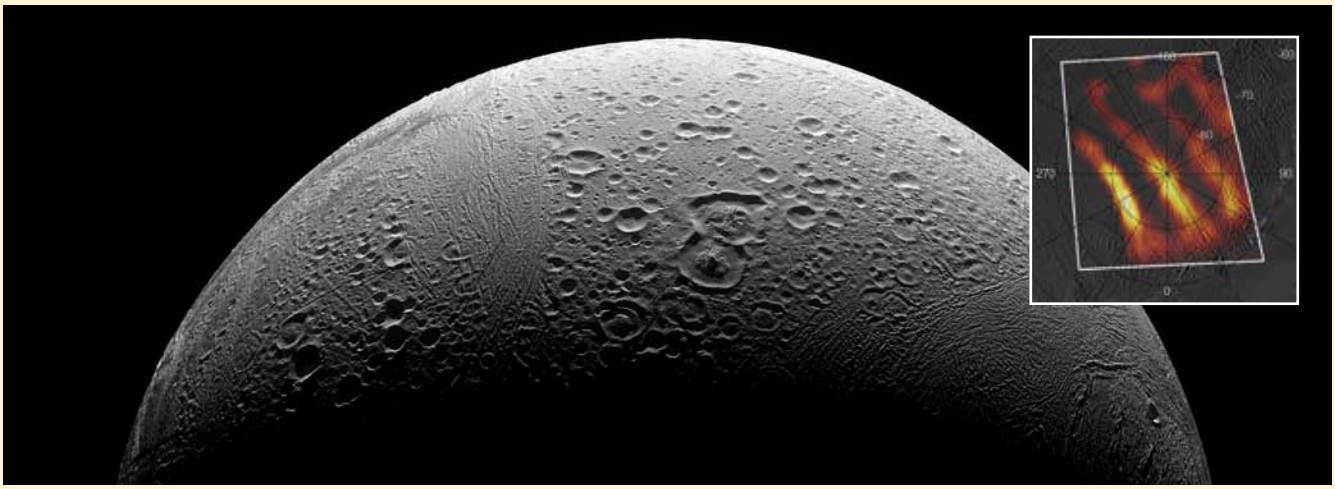
But perhaps most spectacularly, SELENE — short for SELenological and ENgineering Explorer — has snapped images and shot high-definition video of Earth's Moon. Scientists displayed several of the HDTV videos at the 39th Lunar and Planetary Science Conference held in Houston March 10–14.

JAXA/NHK

HIGH DEF. On February 1, Japan's SELENE spacecraft captured this high-definition TV image of the lunar crater Aristarchus and its surroundings.

To date, the spacecraft's HDTV camera has returned more than 50 videos. They show everything from lunar craters, mountains, and maria to the still-enigmatic polar regions, from the probe's 62-mile-high (100 km) orbit. Each segment compresses 8 minutes of the spacecraft's orbital flight time into a single minute of video.

Apollo 17 astronaut Jack Schmitt, who was in the audience watching the videos, claims that they come close to matching what he saw from orbit. That's as close as most of us ever will get. **— R.T.**



NASA/JPL/SSI; INSET: NASA/JPL/GSFC/SWRI/SSI

COLD NORTH. Cassini snapped this image of Enceladus' frigid north polar region from a distance of about 20,000 miles (32,000 km). Mission controllers shut off the camera during Cassini's closest approach. *Inset*: Reds and yellows depict the heat radiating from the "tiger stripes" traversing Enceladus' south pole. The moon's geyser-like plumes arise from the warmest parts of the fissures.

Cassini "tastes" Enceladus' plumes

On March 12, NASA's Cassini spacecraft flew through plumes erupting from Saturn's moon Enceladus. The probe sampled these jets and found them rich in water vapor, carbon monoxide, carbon dioxide, and organic material — and some 20 times denser than expected.

The chemistry of Enceladus resembles that of a comet, says Hunter Waite of the Southwest Research Institute (SwRI) in San Antonio, principal investigator for Cassini's Ion and Neutral Mass Spectrometer. "Enceladus' brew is like carbonated water with an essence of natural gas," he says.

The jets harmlessly peppered the spacecraft as it flew within 120 miles (200 km) of the moon's surface, its closest flyby of the mission. The jets erupt from fissures near the moon's south pole. Cassini found the fissures to be warm along nearly their entire lengths. Temperatures in the fissures reached at least –135° Fahrenheit (–93° Celsius), some 207° F (115° C) warmer than the rest of the moon and 63° F (35° C) higher than previous measurements.

"The surprisingly high temperatures make it more likely that there's liquid water not far below the surface," says Cassini scientist John Spencer at SwRI in Boulder, Colorado. **— R.T.**

NASA

ROLL 'EM. A lunar truck prototype negotiates the Moon-like Lunar Yard at NASA's Johnson Space Center in Houston.

Six-wheelin' with NASA's Moon truck

In February, engineers at NASA's Johnson Space Center in Houston rolled out their concept of a future lunar rover. The strange new ride features active suspension and six-wheel drive, but lacks doors, windows, and seats. It comes in any color you want, as long as it's gold.

Designers were told to throw away old assumptions. "It was scary when we started," says Lucien Junkin, the project's lead designer. "They tasked us … to build the next-generation rover and challenge the conventional wisdom."

The first expectation to go is that a vehicle needs four wheels. The continuing success of the Mars rovers Spirit and Opportunity prove the value of having extra wheels. On the lunar truck, each of the six wheels can pivot individually in any direction.

To parallel park, a driver could pull up next to the parking spot, turn all the wheels to the right, and roll in. While that's not a likely situation, the feature, called crab steering, gives one advantage to a vehicle off-roading into craters. To avoid a slope considered too steep for safe driving, the truck can roll sideways instead of backing up.

Because the truck's wheels can drive in different directions, the driver must be able to do the same, so both the steering mechanism and the driver can pivot 360°. The reason the driver stands, the designers say, is because sitting in a spacesuit is neither comfortable nor practical. — **F. R.**

Are we looking in the

For years, astrobiologists have looked for life on other worlds by "following the water." But could other substances hold the key?

/// BY DANIEL PENDICK

A veritable army of planetary scientists and astrobiologists is searching for life beyond Earth. The effort focuses on Mars at the moment, but plans are in the works to investigate oceans thought to be under the ice of Jupiter's moon Europa and the hydrocarbon lakes and plains of Saturn's largest satellite, Titan.

Discovering extraterrestrial life certainly would be one of the most exciting scientific discoveries in history. But searching for and failing to find life where it does exist would be a blunder of cosmic proportions.

"Nothing would be more tragic in the American exploration of space than to encounter alien life and fail to recognize it because of the lack of proper tools and scientific preparation," says John Baross, a biologist and oceanographer at the University of Washington, Seattle. He chaired the 10-member team that wrote an influential report about the search for life last year.

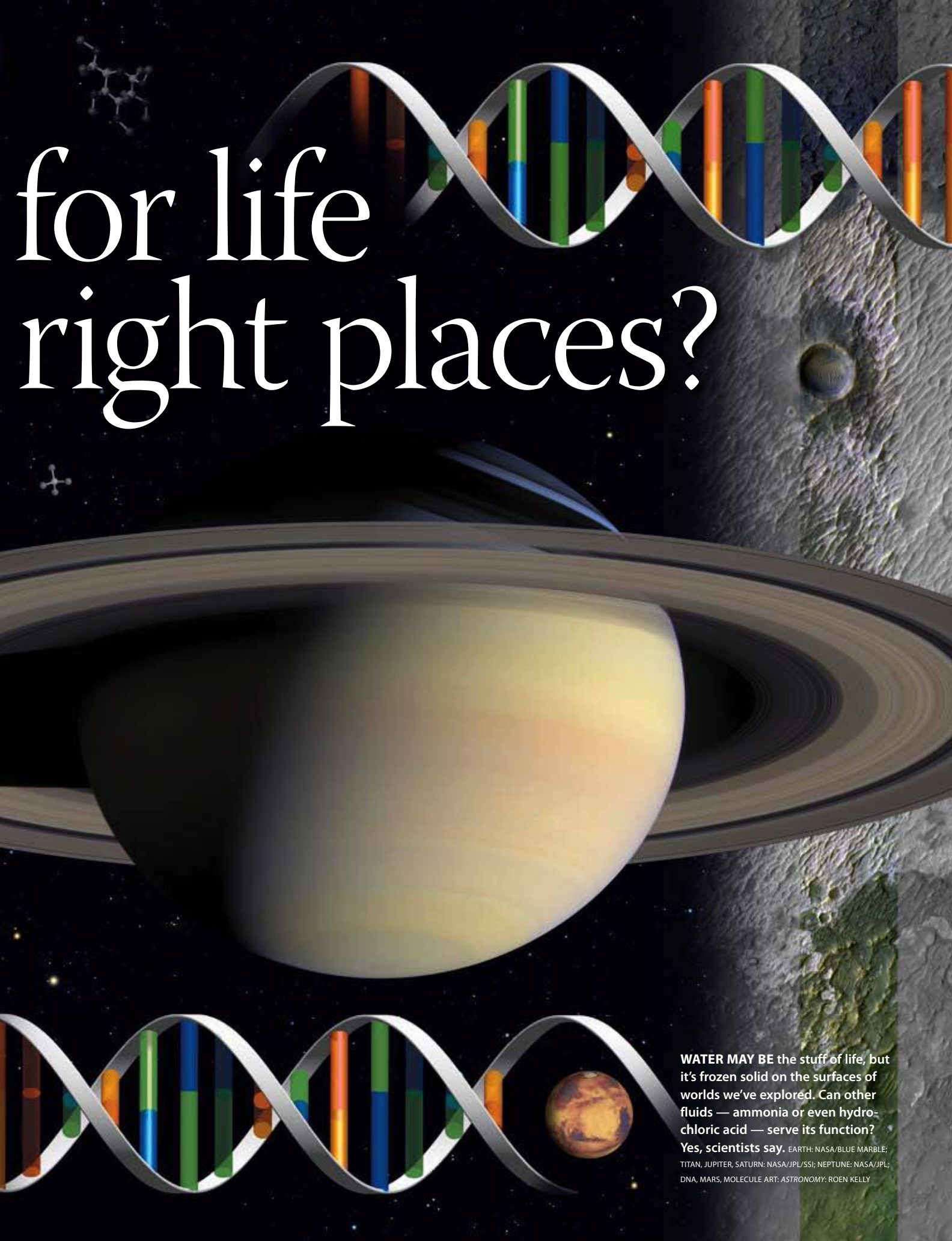
NASA commissioned and financed the National Academy of Sciences report to assess our current search strategy and recommend any needed changes for the future. The document, titled "The limits of organic life in planetary systems," already is influencing how mission planners think about biological tests on future space probes.

Perhaps most importantly, the Baross report has helped planetary scientists think more about life as we *don't* know it, as opposed to life as we find it here on Earth. "It's a useful caution to the community," says Michael Meyer, lead scientist for NASA's Mars Exploration Program at the U.S. space agency's Washington headquarters.

The report's most significant influence may be felt in the next decades, as scientists propose and design new instruments to search for extraterrestrial organisms. The bottom line: Astrobiologists should prepare themselves to look for — and hopefully find — "weird" life.

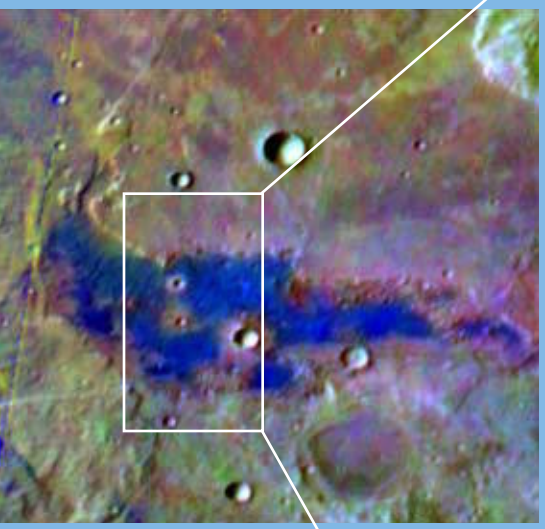
"It is critical to know what to look for in the search for life in the solar system," Baross explains. "The search so far has focused on earthlike life because that's all we know. But life that may have originated elsewhere could be unrecognizable compared with life here."

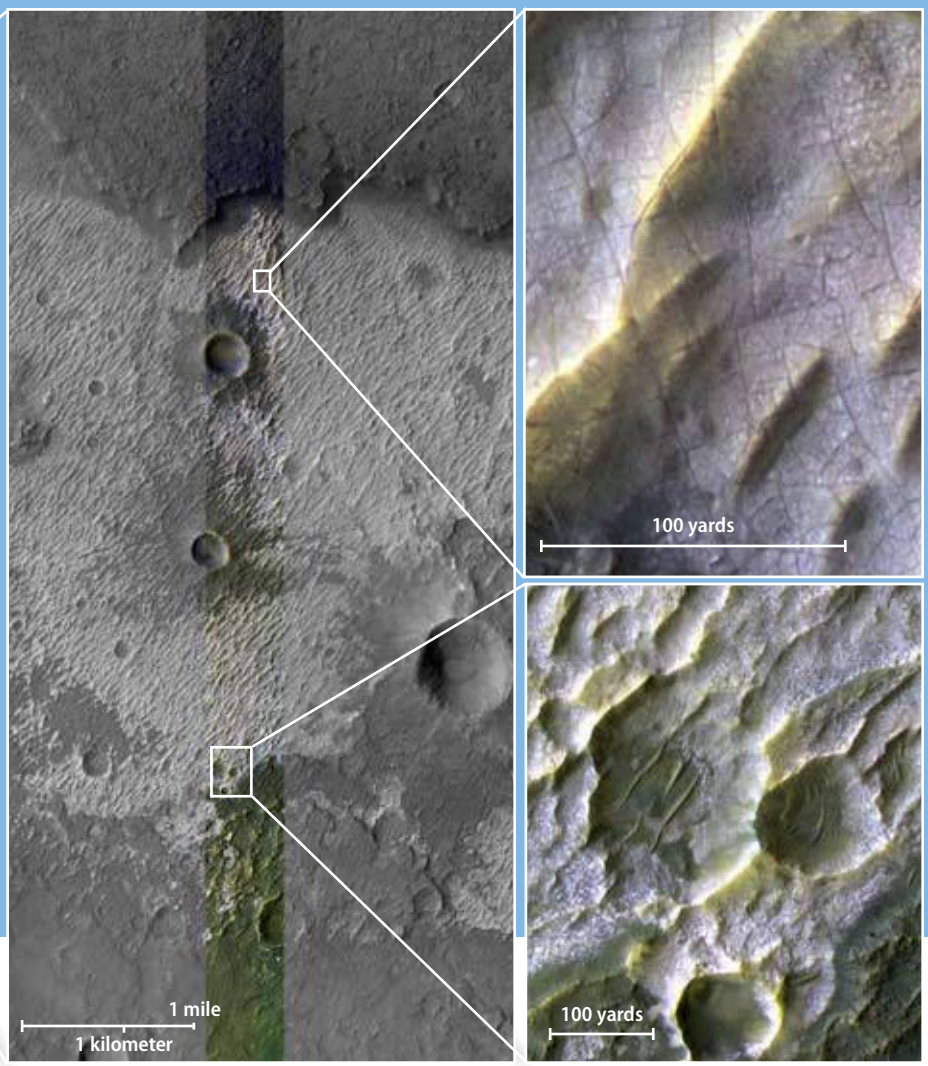
for life right places?



WATER MAY BE the stuff of life, but it's frozen solid on the surfaces of worlds we've explored. Can other fluids — ammonia or even hydrochloric acid — serve its function? **Yes, scientists say.** EARTH: NASA/BLUE MARBLE; TITAN, JUPITER, SATURN: NASA/JPL/SSI; NEPTUNE: NASA/JPL; DNA, MARS, MOLECULE ART: *ASTRONOMY*: ROEN KELLY

A martian salt pan





NASA'S MARS ODYSSEY spacecraft identified chloride minerals (salt, shown as blue in the false-color image above) on the surface in the Red Planet's southern highlands. Scientists say these depressions probably were filled with groundwater at some time in Mars' past. When it evaporated, the salt was left behind. NASA/JPL/ARIZONA STATE UNIV./UNIV. OF HAWAII

The fundamental challenge in searching for aliens is not knowing what to look for. After all, nobody — at least, nobody that anybody believes — has seen as much as an alien microbe. This creates a tendency to conceptualize life based on its terrestrial form and risks limiting scientific imagination about the possibilities.

Think of it this way: Imagine a world where architects decided to house people in geodesic domes instead of boxes. A geodesic dome is a hemisphere made from interlocking, triangular panels. You can build them big; you can build them small. They're lightweight, strong, and spacious.

Fast-forward 2,000 years. Geodesic domes carpet the world. Let's say someone on this world now invents a telescope able to see house-sized objects on other planets. Scientists discuss what shapes or patterns would indicate alien buildings. Yet, no matter how hard they try, the experts can envision only variations on geodesic domes.

So it is with the search for life off Earth. Until recently, the strategy has been to define "life" by terrestrial standards, then look for signs of similar biological structures or processes elsewhere.

Wet world

It's now 32 years since the Viking landers scooped up martian soil and performed experiments to look for life. That's where the direct search for life stopped — until the 1990s, when a new generation of orbiters and landers arrived on Mars. Their goal: Find the water and follow it — with robot rovers — to places where life might once have existed.

What drives NASA's "follow the water" strategy for Mars is our understanding of liquid water as a fundamental requirement of terrestrial life. Biologists haven't found a single organism that can survive without it.

It turns out Earth's living creatures do a good job of metabolizing chemicals only when the substances are dissolved in water. Water, therefore, is the solvent for life on Earth. No water, no life as we know it.

This connection between water and life on Earth has steered the search for martian life to places that now may be — or once may have been — wet. In fact, this principle is so strong, scientists may be seeing water where it doesn't exist.

In December 2006, NASA released an image taken by the now-defunct Mars Global Surveyor. The image showed bright streaks on one wall of an unnamed crater in the Red Planet's Centauri Montes region. Michael Malin of Malin Space Science Systems in San Diego, California, and his colleagues concluded that the streaks formed sometime after 1999 when a gush of liquid water formed gullies on the slope.

John Pelletier at the University of Arizona and his colleagues followed up on this exciting find using images from NASA's Mars Reconnaissance Orbiter (MRO). MRO's high-resolution camera can produce stereo pictures by imaging the same place from different angles.

That data, processed by a computer, enabled scientists to make detailed topographic surface maps. Pelletier's team combined such a map with computer models to conclude that the Centauri Montes streaks

most likely formed through the movement of dry, granular material — like an avalanche on a sandy bluff. Still, they can't rule out a mudslide composed of a 50- to 60-percent soil-water mix.

Other solvents

Mars is a logical place to seek water-based life thanks to growing evidence that it once was a wet place, possibly with shallow seas. When robotic laboratories finally reach these possible past or present habitats, they would logically look for organisms that run on chemical reactions involving water. On other worlds, though, planetary scientists will have to think more broadly.

In theory, biochemical reactions could occur in solvents other than water — for example, liquid ammonia and methane on Titan. Some scientists have looked at more exotic possibilities, like life in liquid nitrogen on Neptune's moon Triton or in supercold mixtures of hydrogen and helium, such as those making up gas giants like Jupiter.

The hypothetical possibility of life using alternate solvents is why the Baross committee recommended that NASA put a high priority on a follow-up mission to Titan, with its liquid lakes and complex hydrocarbon haze. Another solvent scientists have considered as a host for life is formamide, a chemical used in manufacturing that dissolves many compounds that water cannot.

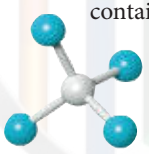
One bizarre-seeming alternative solvent astrobiologists have pondered is hydrochloric acid. (Think back to the acid-drooling monsters in the *Alien* movie franchise.) Hydrochloric acid can melt your face off — if it's mixed with water. But alone, it's not very corrosive and can form the basis for life-supporting biochemistries.

Carbon-copy extraterrestrials?

Just about everybody has heard the phrase "carbon-based life." Carbon-containing molecules are, in a sense, the scaffolding for organic molecules on Earth.

More accurately, life on Earth is "CHON-based." Organic chemistry — the universe of reactions that powers life — involves complex molecules containing carbon, hydrogen, oxygen, and nitrogen. Phosphorous and sulfur also play important roles in organic reactions.

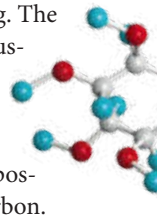
That teaspoon of sugar in your coffee contains sucrose, a carbohydrate. Its molecules comprise arrangements of 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms — $C_{12}H_{22}O_{11}$, in chemical shorthand.



Glucose is the form of sugar your body's cells burn as fuel. Its molecules contain six carbon atoms, 12 hydrogen atoms, and six oxygen atoms ($C_6H_{12}O_6$). Your body metabolizes food to make glucose, then shoots it into the bloodstream so cells can use it for energy.

Wherever you look on Earth, you'll find biochemical molecules containing carbon. And in the search for life, scientists often have assumed it will be carbon-based. This is not a thoughtless conclusion. "Carbon is great for life," Meyer says. When astronomers using radio telescopes gaze into the chemicals floating between stars — the so-called interstellar medium — "all complex molecules we see contain carbon," he notes. Carbonaceous-chondrite meteorites are full of carbon-based stuff, including amino acids — the basis for building proteins.

But the larger point, Meyer stresses, is to look for complex molecules of the sort involved in biochemical reactions on Earth. One of Earth's most abundant such molecules is chlorophyll, the green pigment in plants that converts sunlight and water into carbohydrates and carbon-dioxide gas. The chemical formula for chlorophyll-a, the most common form, is $C_{55}H_{72}O_5N_4Mg$. The molecule contains the usual CHON suspects, along with magnesium.



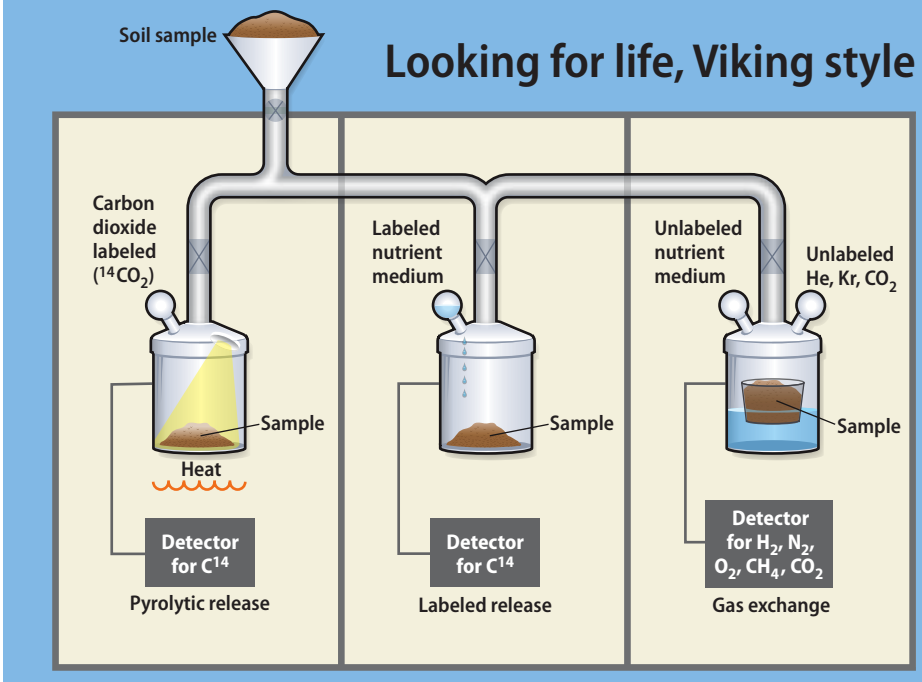
Other scaffolds

The Baross report stresses that other possible "scaffold atoms" exist besides carbon. And we should be sufficiently aware of this fact to let it influence the design and destinations of biological detectors.

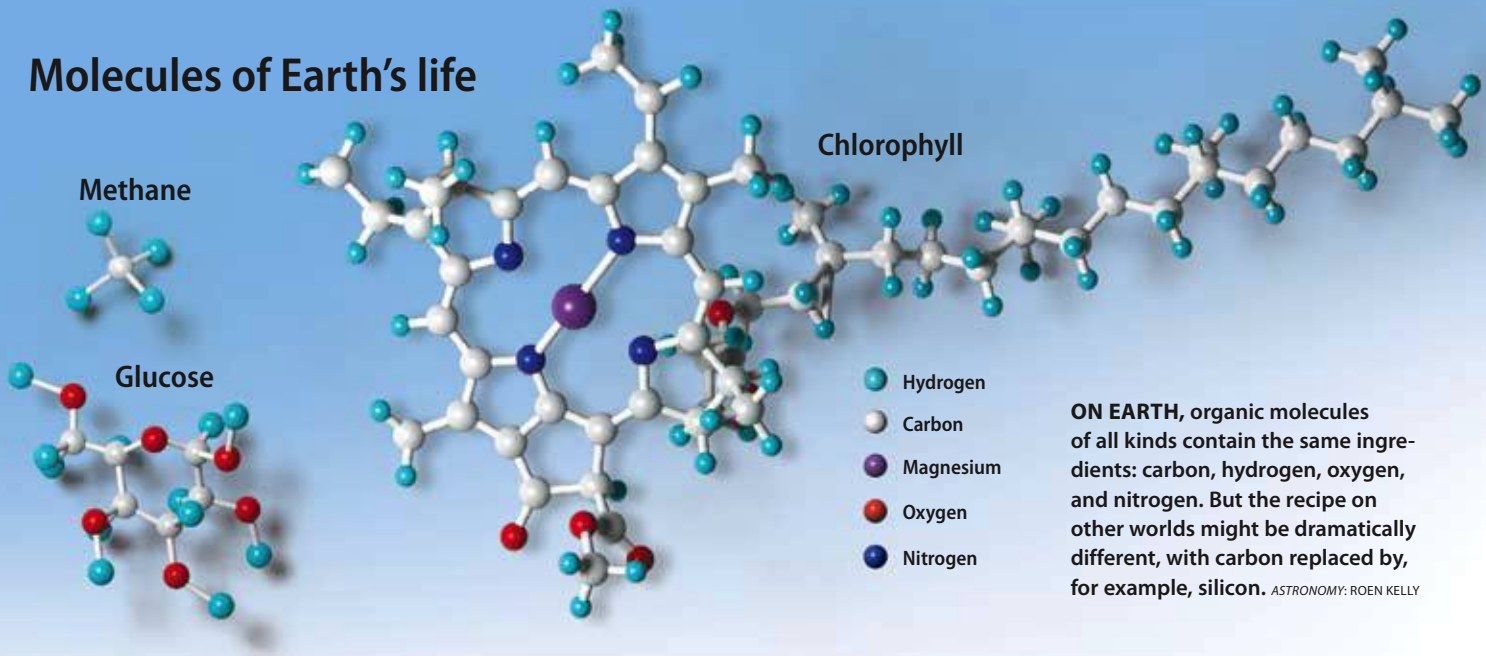
Silicon is one atom often considered as having a potential role for life. It all comes down to basics like temperature. Carbon-based molecules can't function above temperatures of about 130° Fahrenheit (54° Celsius). In fact, they simply fall apart.

Conversely, at temperatures below –190° F (–123° C), common terrestrial chemical reactions run slowly or not at all because there's insufficient energy to form chemical bonds. These temperatures are the rule in the outer solar system. On Saturn's moon Titan, a liquid solvent (methane) and

Daniel Pendick *is an associate editor of* Astronomy.



THREE BIOLOGY EXPERIMENTS were performed on Mars by NASA's Viking 1 and 2 landers in 1976. Each test involved the incubation of martian soil samples under controlled conditions. The pyrolytic-release experiment (left) added radioactive carbon-14 (C^{14}) to the martian atmosphere to look for molecules built by living organisms. The labeled-release experiment (center) delivered water and nutrients laced with C^{14} to each sample, then looked for increased radioactivity as organisms consumed the nutrient and released waste gases. The gas-exchange experiment (right) monitored how concentrations of certain gases changed when samples were given C^{14}-enriched water. *ASTRONOMY:* ROEN KELLY



ON EARTH, organic molecules of all kinds contain the same ingredients: carbon, hydrogen, oxygen, and nitrogen. But the recipe on other worlds might be dramatically different, with carbon replaced by, for example, silicon. *ASTRONOMY:* ROEN KELLY

organic molecules exist, but carbon-based life probably cannot.

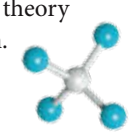
Silicon could solve the low-temperature problem. Its atoms can form bonds at cold temperatures and join into chains as long as 30 atoms, explains organic chemist Steven Benner. A fellow at the Foundation for Applied Molecular Evolution at the University of Florida, Gainesville, Benner served on the Baross committee.

Silicon can bond with oxygen to create reactive substances that, in theory, could form larger molecules. Some scientists have speculated that life could exist in clay, which consists of silicon and oxygen molecules. If so, the substance would be a living mineral. (Then again, if you count water as a mineral, so are we.)

Much work remains to be done before we can seek exotic biochemistries, Benner says. He's seen other scientists work out exotic chemical reactions that potentially could form the basis for metabolism on other worlds. But would they actually work?

Some scientists argue that "chemistry intrinsically wants to assemble itself into ordered structures and from those will emerge life-like behavior," Benner says. "But if you're an organic chemist, which is what I am, you've never seen that happen in the lab."

Cooks know that chemistry goes the other way. "If I take a soufflé and put energy into it, it does not start to walk around the room and talk," Benner notes. Chemical reactions that work in theory may not work on Triton or Titan.



Different DNA

Another universal aspect of life as we know it on Earth is Darwinian evolution. But, as it turns out, what Darwin called natural selection depends entirely on our DNA-based life plan.

Four different kinds of "bases," or nucleotides, form the rungs of the DNA molecule's twisted-ladder shape. The rungs attach to spiraling backbones of phosphorous-based molecules.

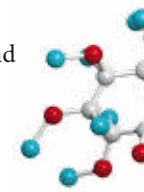
DNA stores information, like how to build the proteins that form our physical bodies. Natural genetic variation — chance changes in genetic programming — alter the shapes and functions of organisms. Some of this tinkering makes variants that work better, and some doesn't.

Changes can be adaptive: They allow an organism to better exploit its environment and flourish. Adaptive traits persist. They're handed to the next generation through reproduction. Unsuccessful variations get pruned from the tree of life. That's called extinction.

In a neat package, Darwinian evolution explains the incredible diversity of life, the fossil record, relationships between different organisms, and just about everything else we see in nature. But in "weird" terrestrial life, Darwinian evolution might take alternative forms.

For one thing, an organism might have the equivalent of DNA, but a version with six or more bases. It may not look like a twisted ladder. Many possibilities exist for alternative genetic systems. Benner's group has synthesized alternative DNA bases, as have other researchers.

But it goes further than that. On Earth, all proteins are made of 20 different molecules called amino acids. They form chains and fold up into complex shapes. Benner calculates that chemical rules allow for as many as 256 different kinds of amino acids. The Baross report recommends that future missions be prepared to detect unexpected and exotic nucleic acids and DNA-like molecules.



Dumping Darwin

As for Darwinian evolution, it may not dominate alien life as much as on Earth. This is especially true when it comes to microbial life, explains Carol Cleland, a philosopher at the Center for Astrobiology at the University of Colorado in Boulder.

Talk about weird life: Plasmids are ring-shaped packages of genetic material in bacteria that exist independently of the bacteria's tightly coiled DNA. Bacteria use them for a process called horizontal gene transfer — a process at odds with the conventional role of DNA in natural selection.

For example, when a bacterium becomes resistant to the effects of a certain antibiotic, it can transfer that handy survival skill directly to other bacteria by transferring a plasmid. These "jumping genes" are one reason why drug-resistant microbes are becoming more common.

Cleland emphasizes that when we look for life, a litmus test should not be whether the organism adapts to its environment in a

strict Darwinian sense. As she has argued persuasively to the Baross committee and to astrobiologists at large, "Darwinian evolution" is a characteristic of all known Earth life but it emphatically is not part of the definition of all life. Darwinian evolution doesn't tell us how to recognize living things in general, and we can't exclude the possibility that alien microbes might evolve by means of some other mechanism.

Darwinian evolution is what shaped all life on Earth. The evidence for this is overwhelming. But on Mars or elsewhere — who knows? It's possible microbial aliens could, for example, develop a novel way to change in response to their environments. They could split into identical copies, each having the traits the original cell acquired without changing a gene-like molecule.

The game of life

What we really need, Cleland says, is a "theory of life." That will require discovering alien organisms to compare and contrast to Earth life.

It also would help to find life here on Earth that does not play by the conventional rules. These would be organisms that descended from a different origin of life but didn't end up dominating the planet. They could remain hidden in undersea volcanic vents or deep underground. By studying life as we don't know it, we would truly understand life as we do know it — as well as life as a general cosmic phenomenon.

Cleland compares it to the development of Newton's universal theory of gravity. If Newton had merely contemplated objects dropping straight down — the proverbial apple falling from the tree — he might not have experienced his brilliant insight. But when he observed other phenomena, like balls rolling down inclined planes and artillery shells tracing perfect parabolic arcs through the sky, Newton realized they all followed the same rules.

BACTERIA THRIVE under Lake Vanda in Antarctica. Algae form complex mats even in the water's cold temperature and nutrient-poor conditions. DALE ANDERSEN

Thus was born the *Philosophiæ Naturalis Principia Mathematica*, in which Newton neatly summarized the mathematics underlying gravity. This allows us to target mortar shells and steer space probes a billion miles.

Cleland imagines — hopes for — a sort of *Principia Vivo*. A theory that explains the underlying principles of life would make predictions about what sorts of life could develop under a given set of conditions. That, ultimately, could allow us to program space probes to search for life without taking along a team of biochemists.

The next step

The search for life on Mars and its "follow-the-water" strategy remains on track. Several NASA and European Space Agency (ESA) missions are in the works, including the Phoenix lander, the roving Mars Science Laboratory, ESA's mobile ExoMars project, and, one day, a sample-return mission.

Elsewhere in the solar system, scientists have yet to decide where and when to go. But the Baross report has had repercussions among astrobiologists and planetary scientists who are thinking about future missions beyond Mars.

A team of astrobiologists have put together a major new proposal for a mission to Titan, in part to look for life. Benner is helping to develop it. "I'm being a little bit more flexible with my speculations now with this proposal because you have to take the next step," he says.

Carol Cleland and the other Baross committee members hope their work will serve as a reminder to think as broadly as possible when searching for life outside Earth. Cleland, in particular, rejects the notion of leaving on the quest with any specific definition of life. It is more likely to limit rather than enhance the search.

But how do you look for alien life without setting search criteria? Cleland's suggestion is to look for oddball features, for strange things in the environment — patterns on the surface, layers in rock, concentrations of chemicals — that might be the result of biological activity.

One specific thing to target, she says, is any kind of gradient: a place that holds more of one thing than another — heat, light, certain chemicals. Then, she says, you investigate the cause.

This makes sense, because on Earth, life is driven by gradients. The vent of an undersea "hot smoker," for example, is highly enriched in sulfur and other chemicals and hotter than its surroundings. That's how vent communities became established: Organisms exploit both chemical and thermal gradients.

Even though Cleland's search would be based on a criterion for life on Earth — gradients — it doesn't conflict with her fundamental point about keeping an open mind. "Obviously, we have to base the search for life on familiar life on Earth," she says. "That's our only example. What we don't want to do is allow it to blinker us to alternative possibilities."

In the future, one thing is possible: The search for alien organisms in the solar system could introduce us not only to life as we don't know it, but life as we can't even imagine it — yet.

TITAN'S FRIGID surface is likely rich in hydrocarbons. Could an ecosystem have developed on the saturnian moon? STEPHAN HOBBES/ESA

Blowin' in the wind

The life and death of super suns

Wolf-Rayet stars are big, hot, and bright, spewing gas and dust in all directions. Understanding how they die could help solve the mystery of what triggers the universe's biggest blasts. /// **BY ROBERT ZIMMERMAN**

▲ **IN THE HEART** of Thor's Helmet, the Wolf-Rayet star WR 7 feeds the surrounding nebula with its powerful stellar wind. In its Wolf-Rayet stage, a star may shed half its mass — raw materials for stunning emission nebulae like Thor's Helmet.

CFHT/JEAN-CHARLES CUILLANDRE/COELUM

◀ **BIG, BLUE, AND UNRULY,** Wolf-Rayet stars sport the hottest surface temperatures and fiercest stellar winds of any type of star known. In this artist's conception, the star is partly obscured by gas and dust ejected from its surface at speeds as high as 7 million mph (11 million km/h).

NASA/DANA BERRY/SKYWORKS DIGITAL

For many people, old age is a time of declining vitality — a time when we become less energetic, more sedentary. Not so for big stars. When a massive star becomes a senior citizen, it starts acting like a badly behaved teenager: loud and aggressive, prone to sudden outbursts, and apt to wreak havoc on everything in the neighborhood.

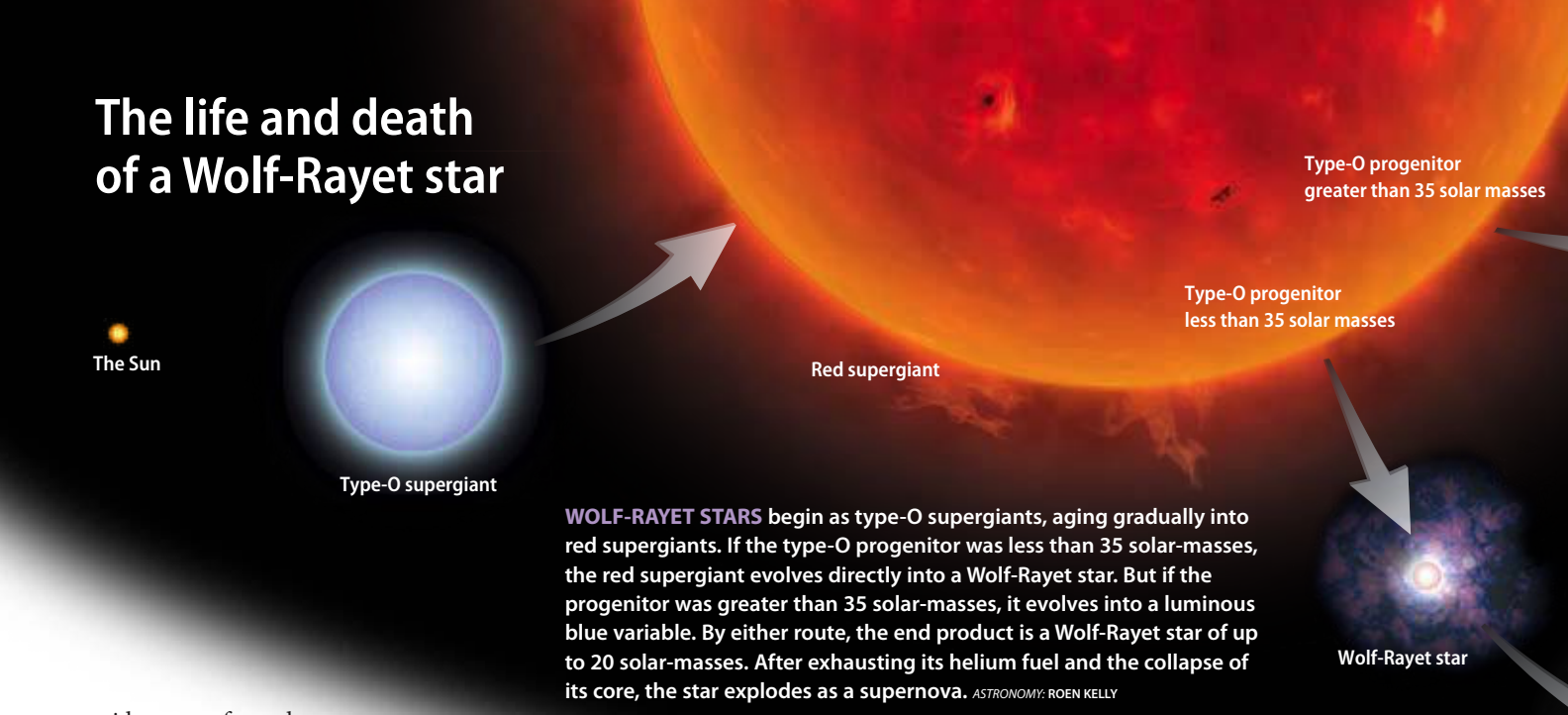
Astronomers call this last stage of stellar life a Wolf-Rayet star. Immense and luminous, Wolf-Rayet stars make our Sun seem dim in comparison. In fact, Wolf-Rayet stars radiate so much light and heat, they force their own outer gas shells to flee. The star's stellar wind blows at up to 7 million mph (11 million km/h).

The Wolf-Rayet stage of a star's life is short. Whereas the Sun has burned for 4.5 billion years and will continue to do so for billions more, Wolf-Rayet stars typically exist for less than a million years. As the star consumes its nuclear fuel, chemical changes occur deep inside. At some point, its core collapses.

When a Wolf-Rayet star's death rattle finally comes, watch out! It will announce its demise in the most spectacular way imaginable: a supernova blast visible for billions of light-years. It might even trigger a gamma-ray burst, the brightest explosion of energy in the universe.

Three strange stars

In 1867, while surveying the spectra of stars in the constellation Cygnus, Charles Wolf and Georges Rayet of the Paris Observatory discovered three strange stars. The spectrum of each displayed unusually wide, bright emission lines, suggesting the material producing the lines was traveling at a


The life and death of a Wolf-Rayet star
Type-O progenitor greater than 35 solar masses
Type-O progenitor less than 35 solar masses
The Sun
Red supergiant
Type-O supergiant
Wolf-Rayet star

WOLF-RAYET STARS begin as type-O supergiants, aging gradually into red supergiants. If the type-O progenitor was less than 35 solar-masses, the red supergiant evolves directly into a Wolf-Rayet star. But if the progenitor was greater than 35 solar-masses, it evolves into a luminous blue variable. By either route, the end product is a Wolf-Rayet star of up to 20 solar-masses. After exhausting its helium fuel and the collapse of its core, the star explodes as a supernova. *ASTRONOMY:* ROEN KELLY

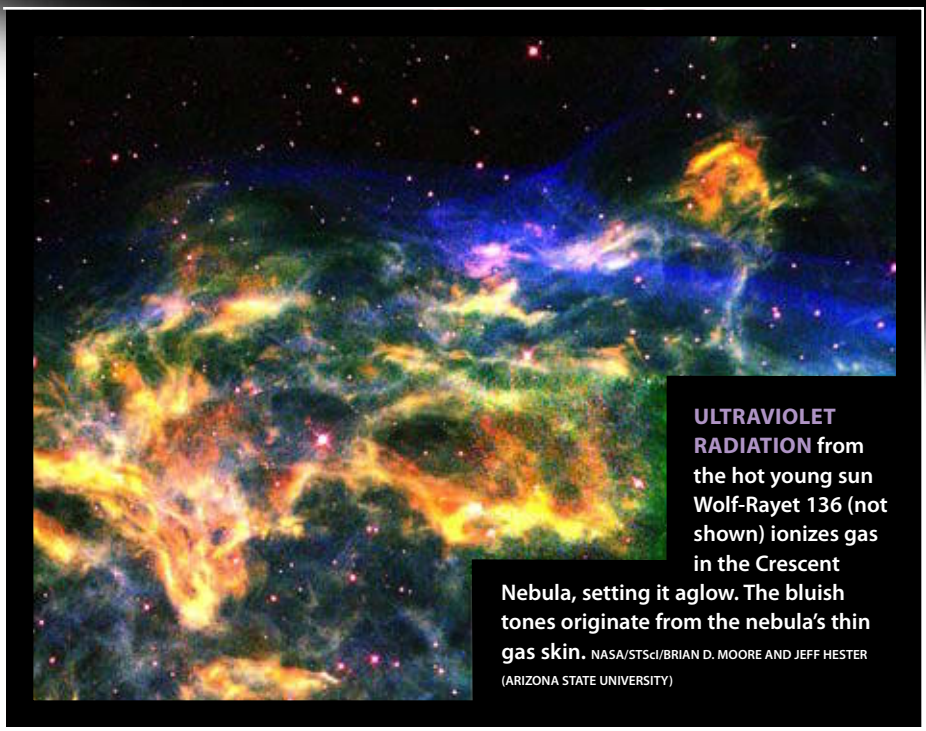
wide range of speeds. Astronomers had not seen this before. Although dozens more such stars were found during the next few decades — dubbed Wolf-Rayet stars in honor of their discoverers — observers remained baffled by the oddball spectra of the objects.

Then, in 1929, Canadian astronomer Carlyle S. Beals proposed an explanation for the broad emission lines of Wolf-Rayet stars. They reflect a dense outflow of material expanding at a tremendous velocity — what astronomers today call a stellar wind. The wind is so intense it can cast off the entire mass of the Sun every 100,000 years — the fastest mass-loss rate of any kind of star. And it's so dense it actually hides these stars from view. When we look at a Wolf-Rayet star, we see only the bright cloud of material around it.

Everything about Wolf-Rayet stars is unusual. For one thing, they are exceedingly rare. Astronomers have found only about 300 Wolf-Rayet stars in the entire Milky Way, concentrated in the galaxy's inner spiral arms and core.

Wolf-Rayet stars are large, ranging from 7 to 20 solar-masses (7 to 20 times the mass of the Sun). They also are among the hottest stars, with surface temperatures up to 100,000 kelvins (180,000° F), about 15 times hotter than our Sun.

Robert Zimmerman *is a frequent contributor to* Astronomy. *His latest book is* The Universe in a Mirror: The Saga of the Hubble Space Telescope and the Visionaries Who Built It *(Princeton University Press).*



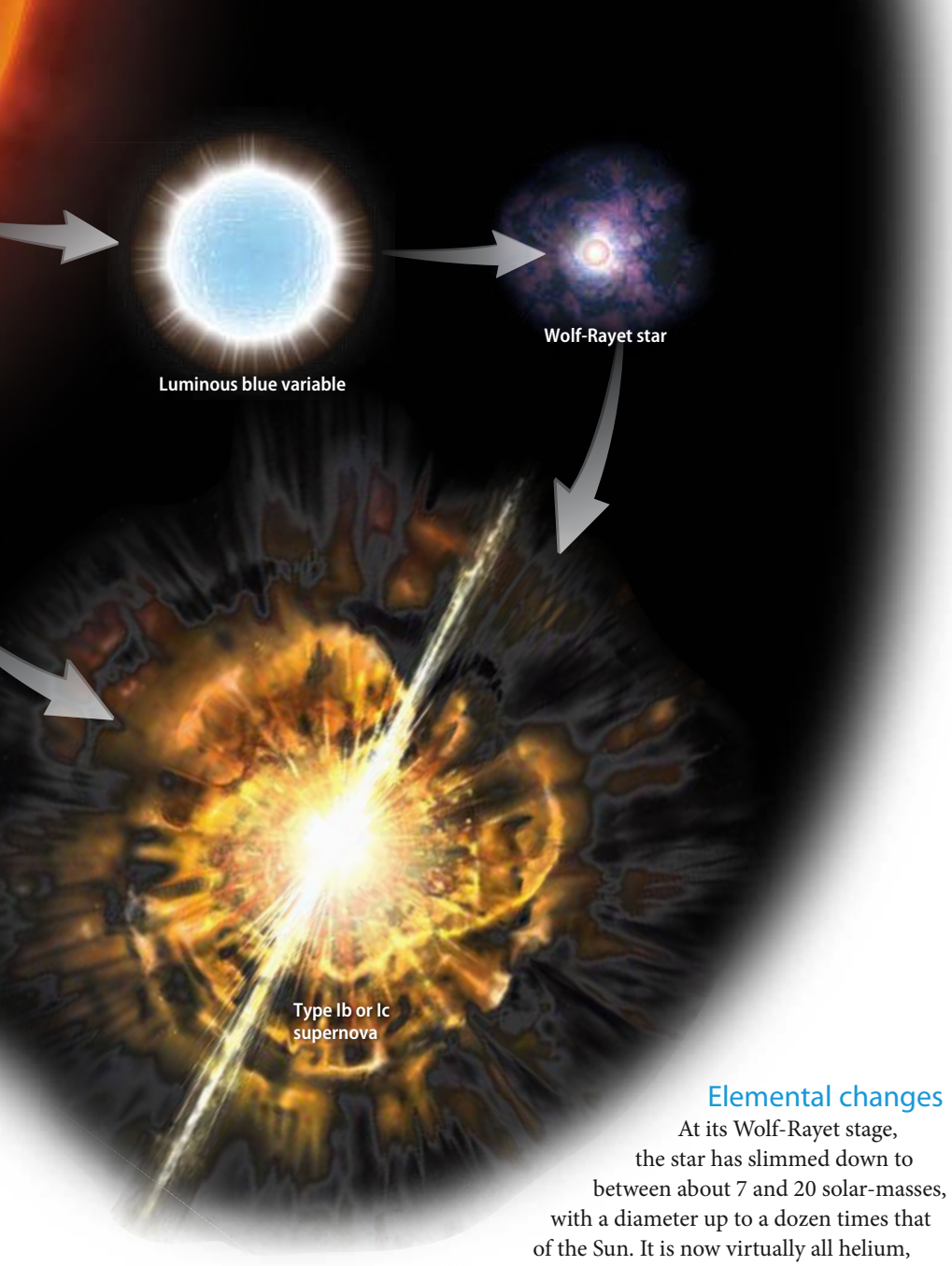
ULTRAVIOLET RADIATION from the hot young sun Wolf-Rayet 136 (not shown) ionizes gas in the Crescent Nebula, setting it aglow. The bluish tones originate from the nebula's thin gas skin. NASA/STScI/BRIAN D. MOORE AND JEFF HESTER (ARIZONA STATE UNIVERSITY)

The luminosity of Wolf-Rayet stars — how much radiation they crank out every second — is truly stupendous: up to 1 million times brighter than the Sun. Their glare often makes them the only individual stars visible in distant galaxies. For this reason, Wolf-Rayet stars are an excellent tool — sometimes the only tool — for studying faint galaxies.

The lives of super suns

Although supremely big, hot, and bright, a Wolf-Rayet star is only a ghost of its youth. It begins its life as a main sequence type-O supergiant star of 25 to 100 or more solar-masses. For 90 percent of its relatively short life span — generally less than several million years — the O supergiant burns hydrogen as fuel and slowly grows a helium core surrounded by a dwindling outer shell of hydrogen gas.

As the star ages, it evolves into a red supergiant like Betelgeuse, the bright star in Orion's left shoulder. Eventually, the red supergiant uses up most of its hydrogen and begins to eat into its helium core. But to fuse helium, the star's core temperature must rise to more than 100 million K.



Rising heat and brightness swell the star's outer gaseous layers.

Some astronomers think if the initial O supergiant is greater than 35 solar-masses, the star becomes unstable at its helium-burning stage and begins to "burp" away its mass periodically in violent and random eruptions. The star evolves into a luminous blue variable, of which Eta Carinae is the textbook example.

Eventually, the blue variable sheds so much mass that virtually nothing is left besides a helium core and a fierce stellar wind: a Wolf-Rayet star. However, theory suggests, if the O supergiant has an initial size less than 35 solar-masses, it takes a different path. It skips the luminous blue variable stage and evolves directly into a Wolf-Rayet star.

Elemental changes

At its Wolf-Rayet stage, the star has slimmed down to between about 7 and 20 solar-masses, with a diameter up to a dozen times that of the Sun. It is now virtually all helium, with a thin remnant layer of hydrogen. The new Wolf-Rayet sun fuses helium to produce heavier elements such as carbon, nitrogen, and oxygen.

Wolf-Rayet stars come in a few basic types. Scientists hypothesize each type represents a different stage in a Wolf-Rayet star's evolution.

Initially, the star burns off its remnant hydrogen fuel and becomes enriched in nitrogen, one of the main byproducts of hydrogen fusion. These stars are called WN stars. Their temperatures range from 30,000 to 40,000 K (54,000° F to 72,000° F).

As the star ages, it burns off its last remaining hydrogen, the core shrinks, the nitrogen dissipates, and its surface temperature rises as high as 100,000 K (180,000° F). Now it has evolved into a WC star enriched in carbon and oxygen, both byproducts of helium fusion.

The hydrogen is gone at this point. In rare cases, Wolf-Rayet stars can evolve to a type enriched in oxygen, called WO stars. Astronomers know of only a handful of WO stars in the Milky Way.

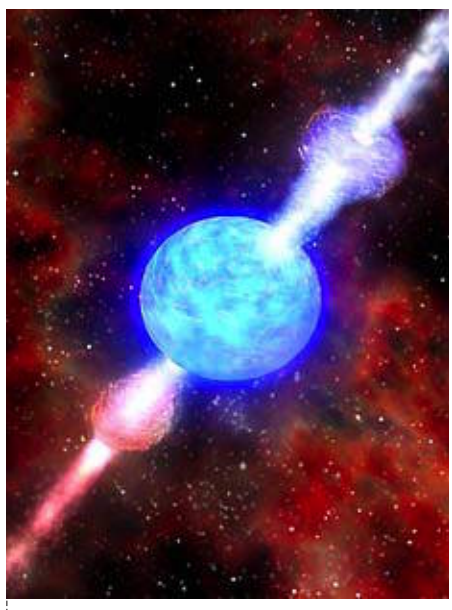
During all these stages, the star continues to cast off approximately 1 solar-mass every 100,000 years. With a starting weight of 7 to 20 solar-masses, this rate of loss is significant. A star in the Wolf-Rayet stage can lose as much as half its mass, all of which is flung into space to become raw material for new stars and planets.

Dust in the wind

For many Wolf-Rayet stars, carbon makes up about 15 percent of their wind. Yet, how they can produce any dust at all has been a great mystery. Dust formation requires a relatively cool, dense environment so atoms can bond and form molecules.

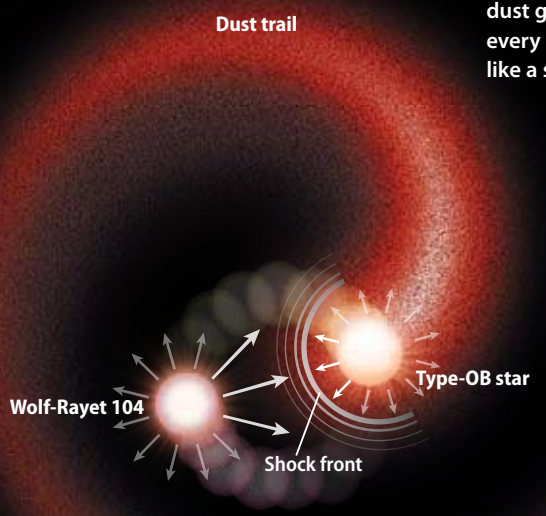
The space close to a Wolf-Rayet star, however, is anything but cool. Basic chemistry suggests it should be impossible for dust to form inside a hot, fast-moving stellar wind. Yet, some Wolf-Rayet stars produce dust continuously; others produce dust in periodic bursts.

Of the periodic dust-producers, the binary star system Wolf-Rayet 140 (WR 140) is probably the best studied. It comprises a Wolf-Rayet star orbited every 7.94

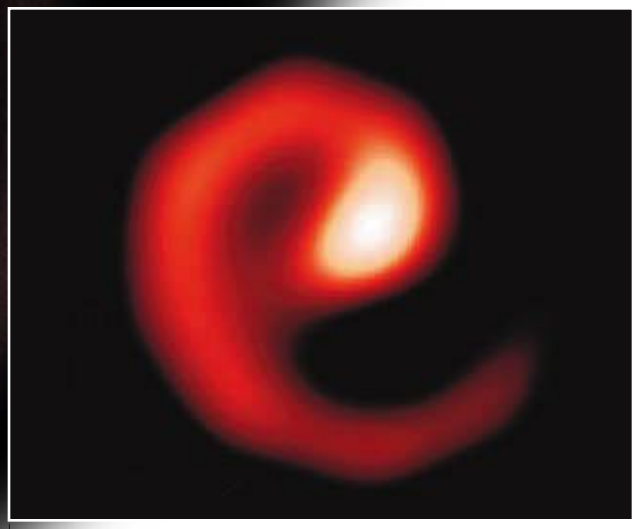


AS IN LIFE, Wolf-Rayet stars blaze brightly when they die as supernovae. Astronomers think some Wolf-Rayet stars unleash gamma-ray bursts, as shown in this artist's depiction. NRAO/AUI AND DANA BERRY (SKYWORKS DIGITAL)

A pinwheel in the sky



HOW DOES THE Wolf-Rayet 104 binary system paint pinwheels in the sky? One hypothesis explains it this way: At the shock front — the collision zone between the stellar winds of the WR star and its type-OB companion — conditions allow dust grains to form. As the OB star orbits the WR star every 241 days, it trails dust in a spiral pattern, like a spinning lawn sprinkler. *ASTRONOMY:* ROEN KELLY



A DUST PINWHEEL swirls around Wolf-Rayet 104 and its binary companion. As the stars circle each other, colliding stellar winds produce an extended dust spiral. UNIVERSITY OF CALIFORNIA, BERKELEY, SPACE SCIENCES LABORATORY/W. M. KECK OBSERVATORY

years by an O supergiant companion. Shortly after the O star makes its closest approach to the primary, the system releases dust into its wind for a few months. It did this in 1985, again in 1993, and once more in February 2001. Presumably, another dust blast is coming in 2009.

What's going on in these dusty Wolf-Rayet systems? One hypothesis links dust production to the conditions created at the collision zone between stellar winds.

According to Robert Becker of the University of California, Davis, and Richard White of the Space Telescope Science Institute in Baltimore, the wind from WR 140 is confined to a narrow disk. When its companion O star sweeps in close, it dives through WR 140's windy disk.

The collision zone creates sufficient density to force carbon atoms to coagulate into molecules; the molecules then form dust particles. However, the physical and chemical details remain unclear.

Many astronomers now believe all dust-forming Wolf-Rayet stars discovered to date must harbor colliding-wind binary systems. Only colliding wind binaries can produce the right conditions needed for dust formation.

Dusty pinwheels

In 1998, astronomers from the University of California, Berkeley, discovered a strange twist — literally — on dust formation in Wolf-Rayet systems. They used the 10-meter Keck I Telescope in Hawaii to take infrared images of WR 104.

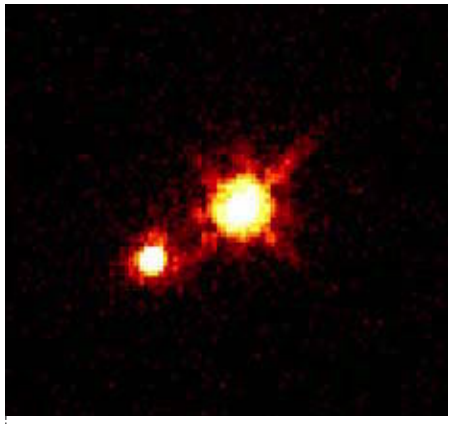
To their astonishment, they discovered a pinwheel-like dust trail spiraling around WR 104 once every 241 days. Only an unseen companion star can explain the pinwheel's cyclic behavior.

"We have many years worth of data, and it spins very, very regularly," says astronomer John Monnier of the University of Michigan in Ann Arbor, one of the discoverers of WR 104's pinwheel. "It's very hard to make something spin like clockwork without it being a binary."

In subsequent years, these astronomers have found dust pinwheels around a number of other Wolf-Rayet stars. Each pinwheel precisely follows the shape of an Archimedean spiral, similar to the architecture of a snail's shell.

Monnier and his colleagues think pinwheels form this way: As the stars circle each other, the Wolf-Rayet's fierce wind overwhelms the slower, less-dense wind of the O star. A dust trail forms behind the O star that points away from the Wolf-Rayet star in much the same way a comet's tail always trails away from the Sun.

Because the O star follows a circular orbit, however, the dust tail is twisted into an expanding spiral, just as water from a spinning garden sprinkler will spiral outward as the nozzle spins. The result is a spectacular expanding pinwheel of dust spanning billions of miles.



A HUBBLE TELESCOPE view of Wolf-Rayet 104 reveals a multiple star system with at least two members. Many Wolf-Rayet stars have companions. STScI DIGITAL SKY SURVEY

How they die

After a few hundred thousand years, a Wolf-Rayet star finally reaches the end of its life. By this time, it has burned off enough of its helium fuel and shed so much mass it can no longer sustain its nuclear reactions. Yet, how the Wolf-Rayet star dies remains unclear.

Strong circumstantial evidence suggests these stars expire as either type Ib or type Ic supernovae. For example, the spectra of both type Ib and Ic supernovae are similar to the spectra of the most evolved Wolf-Rayet stars. "Generally, the Ib supernovae are associated with WN stars and the Ic supernovae are associated with WC stars," notes astronomer Nathan Smith of the University of California, Berkeley.

This evidence implies a physical connection. Wolf-Rayet stars and type Ib and Ic supernova remnants appear to be made of the same stuff; therefore, the supernovae simply may be exploded Wolf-Rayet stars.

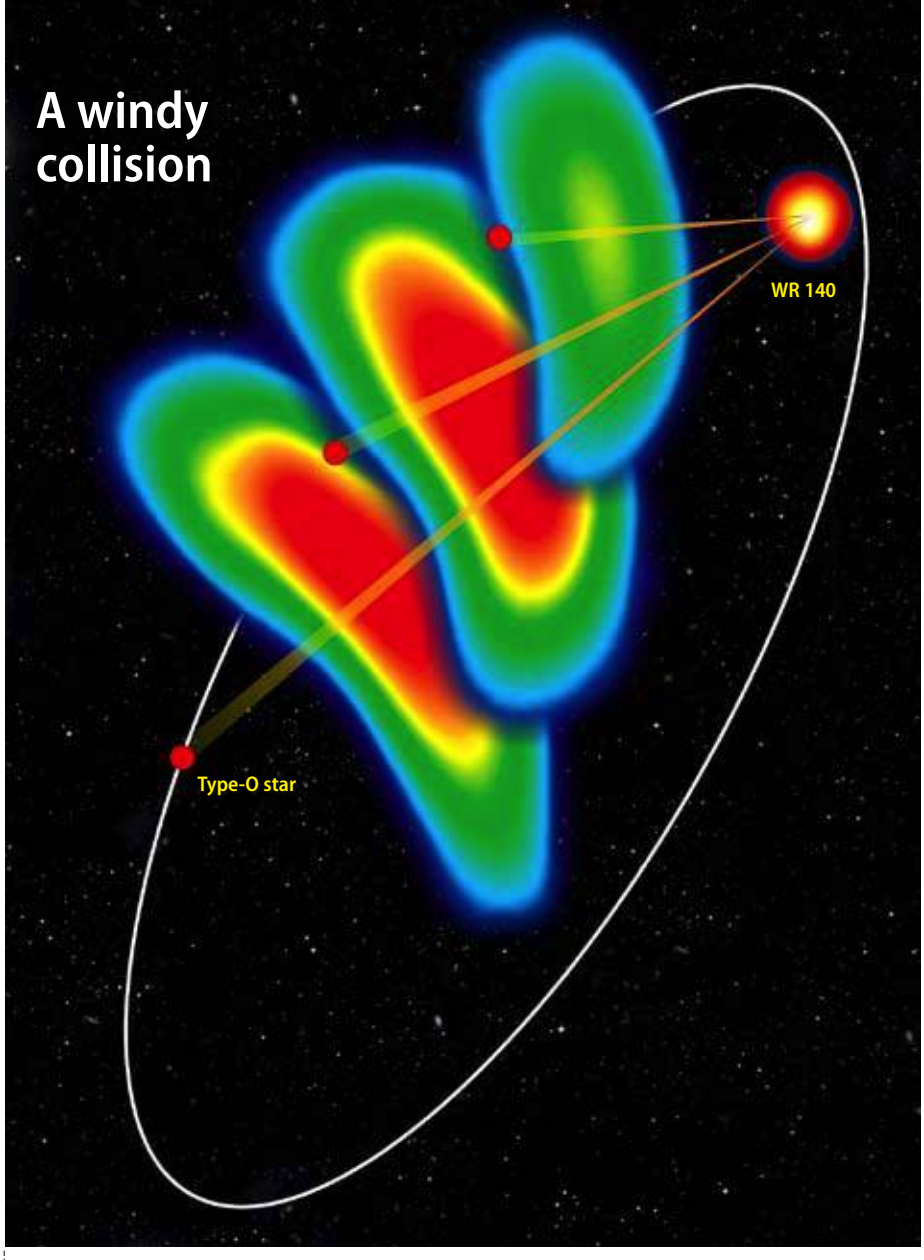
If Wolf-Rayet stars end as type Ib or Ic supernovae, this raises an intriguing possibility. They could be a source of long gamma-ray bursts — outbursts of gamma radiation lasting more than 2 seconds.

In type Ib and Ic supernovae, the star's core collapses and explodes. Then, a black hole forms in the center. A leading explanation for long gamma-ray bursts requires core collapse and rotation. The collapse of a massive, rapidly rotating star unleashes focused jets from the star's poles. Space telescopes detect such an event as a flash of gamma radiation followed by an afterglow of X rays and visible light.

Unfortunately, no direct evidence exists to link Wolf-Rayet supernovae to long gamma-ray bursts. Supernovae are rare — nobody has observed one in the Milky Way Galaxy in more than 400 years — so astronomers have not had the chance to observe a Wolf-Rayet star go supernova.

The only core-collapse supernovae with known progenitors are all blue supergiants, which end in type II supernovae. To date, astronomers have not had the opportunity to study a type Ib or type Ic progenitor star prior to supernova.

Although the spectra of type Ib and Ic supernovae share similarities with those of WN and WC stars, the link between the two phenomena is still unclear. "Exactly where along that sequence the star blows up and what makes it decide to blow up, we don't know," Smith says.



STELLAR WINDS COLLIDE in the binary system comprising Wolf-Rayet 140 (WR 140) and its type-O companion star. Astronomers used the Very Long Baseline Array to observe this system. As the O star nears WR 140, the stellar winds of both stars clash. Radio energy released in the collision zone allowed the researchers to map changes in the zone's position. The changes reflect the O star's distance from WR 140. SEAN DOUGHERTY (NRAO/AUI/NSF)

Monnier adds, "As an observer, I consider the theory of massive star evolution to be very much not finished." Until astronomers actually observe the progenitor of a type Ib or Ic supernova, the evidence will remain circumstantial.

It is even possible, although unlikely, that Wolf-Rayet stars might skip the supernova stage entirely. In this scenario, they would evolve directly into black holes. "The whole star could presumably get sucked into the black hole and you wouldn't even see a supernova," says Smith.

Yet, if some Wolf-Rayet stars end up as supernovae or gamma-ray bursts, it is imperative we identify the most likely candidates to go boom nearby. Fortunately, none of the Wolf-Rayet stars identified so far are very close to home. The nearest, V444 Cygni, lies 3,700 light-years away. Even if it were to blow up tomorrow and create a gamma-ray burst, we are far enough away that the blast wave would not hurt us.

One thing is certain: Wolf-Rayet stars are unpredictable, unruly, and impulsive creatures. And the sooner we can figure them out, the better chance we will have for calm in our own solar neighborhood.

WEB EXTRA Listen to John Monnier explain how astronomers found dust pinwheels at www.Astronomy.com/toc.

JULY 08

Jupiter gleams, Mars glides past Saturn

SATURN AND MARS (right) bookend the Beehive Cluster (M44) in May 2006. This month, the two planets meet again near the bright star Regulus in Leo. TUNÇ TEZEL

Jupiter, the solar system's largest planet, reaches opposition this month, which means the giant world is at its best and brightest all night. Mars chases Saturn above the western horizon in early evening, and the pair enjoys a fine conjunction mid-month. Then, around midnight, the "binocular planets" rise — first Neptune, then, an hour later, Uranus. If your observing stamina lasts through the night early this month, watch for Mercury greeting you in the predawn twilight.

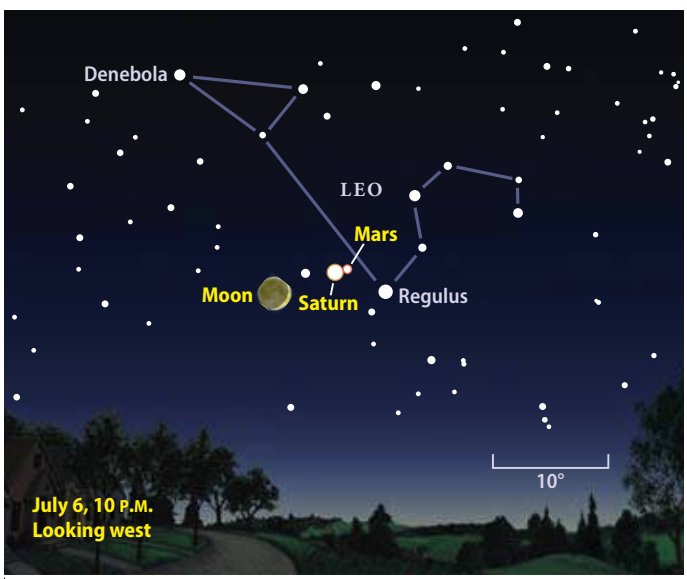
40 See Mars meet Saturn
45 Catch Aquarius fireworks
45 Look for "seas" on the Moon's edge
46 When to view the planets
46 Catch a faint comet
47 Asteroid Juno swings past M10
47 Glimpse a jovian moon lineup

Visible to the naked eye
Visible with binoculars
Visible with a telescope

Keen-eyed skywatchers with a clear western horizon can catch an early glimpse of **Venus**, which is slowly pulling away from the Sun and emerging into the evening sky. On July 1, Venus sets a mere half hour after the Sun. On July 3, a 1-day-old Moon chases Venus to the horizon, setting only 25 minutes after the planet.

Although twilight overwhelms the faint stars of Cancer the Crab, Venus quickly tracks through the Beehive star cluster (M44) July 18. By the 26th, when Venus crosses into Leo, the planet sets 50 minutes after the Sun. Then, you'll find the magnitude –3.9 planet in the west-northwest about 4° above the horizon 15 minutes after sunset. Even so, it'll be at least a month before Venus is worth a telescopic look.

The twilight sky brings a more spectacular display as **Mars** creeps up on Saturn. July — *Continued on page 45*



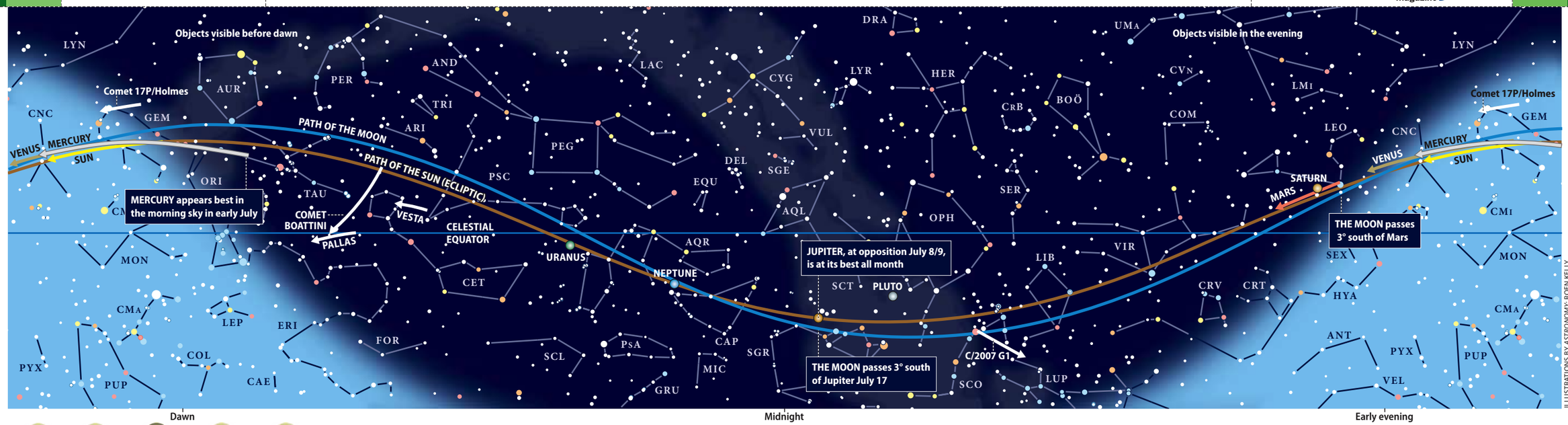
ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

THE CRESCENT MOON JOINS Saturn, Mars, and Regulus July 6, a few days before the two planets appear closest to each other.

Planets in July

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine



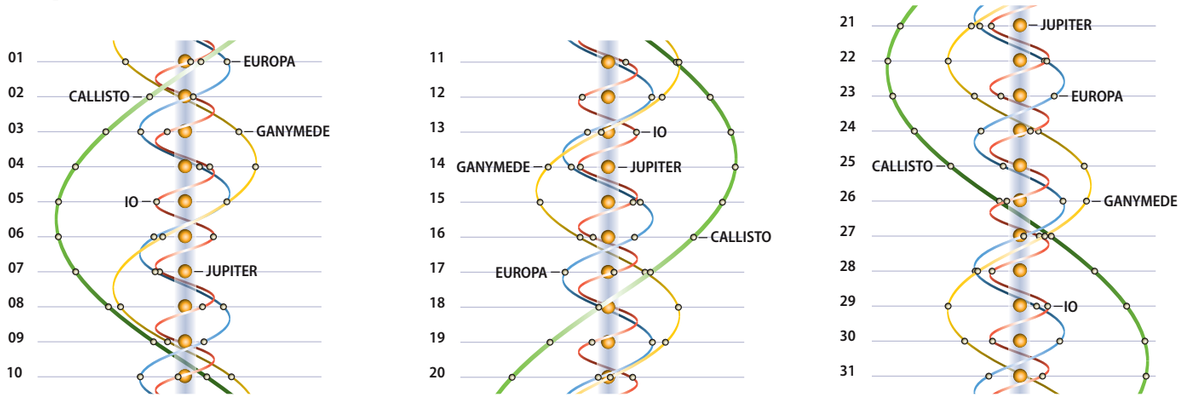
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	July 1	July 31	July 15	July 15	July 15	July 15	July 15	July 15	July 15
Magnitude	0.4	–2.0	–3.9	1.6	–2.7	0.8	5.8	7.9	13.9
Angular size	8.2	5.0"	9.8"	4.4"	47.3"	16.5"	3.6"	2.3"	0.1"
Illumination	35%	100%	99%	94%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.823	1.345	1.698	2.198	5.176	10.036	20.099	29.160	30.563
Distance (AU) from Sun	0.396	0.333	0.718	1.647	4.164	9.319	19.565	30.038	31.491
Right ascension (2000.0)	5h08.6m	8h49.1m	8h20.8m	10h39.7m	19h12.2m	10h32.7m	23h33.3m	21h43.9m	17h56.3m
Declination (2000.0)	19°36'	19°34'	20°47'	9°32'	–22°37'	10°57'	–3°44'	–14°00'	–17°06'

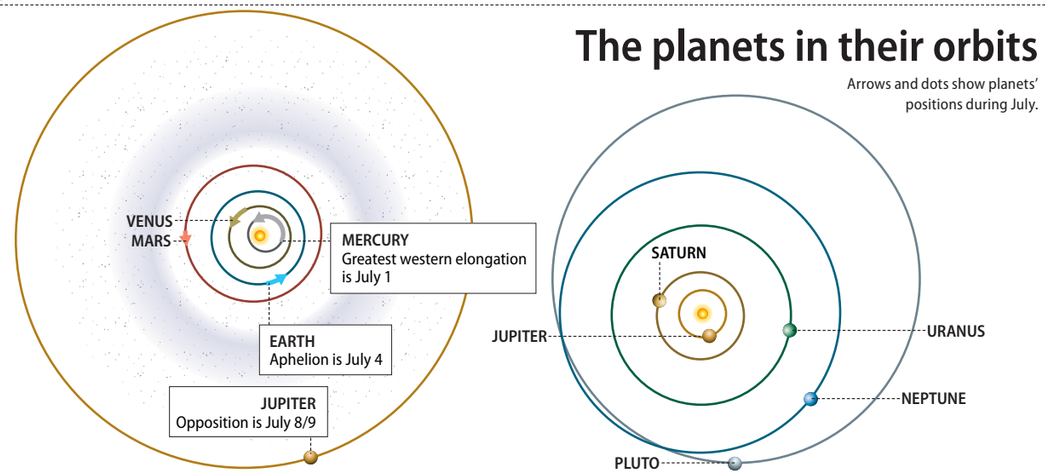
Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.



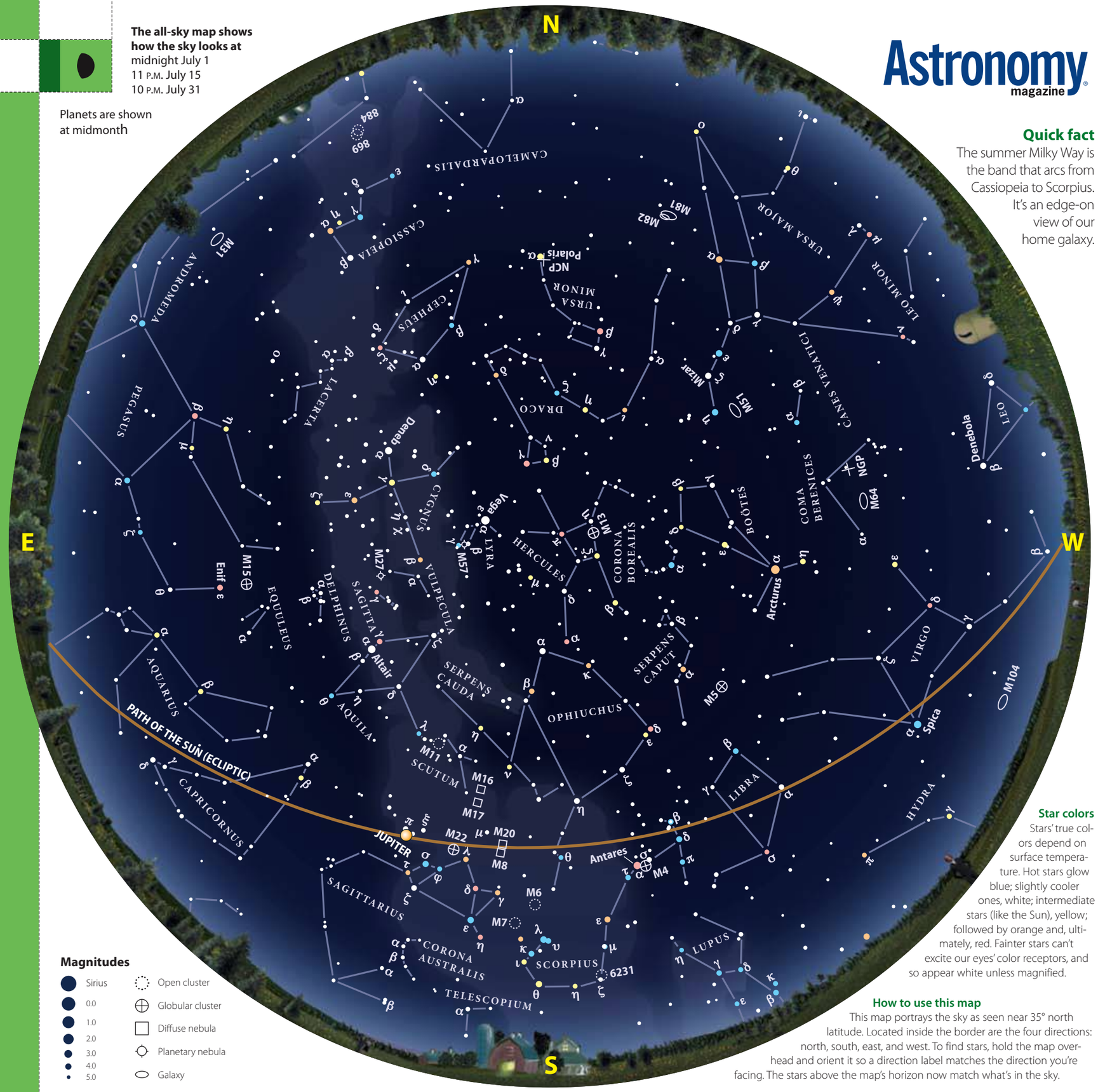
The planets in their orbits

Arrows and dots show planets' positions during July.



The all-sky map shows how the sky looks at
midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

Quick fact
The summer Milky Way is the band that arcs from Cassiopeia to Scorpius. It's an edge-on view of our home galaxy.

NOTABLE OBSERVING DATE
July 10: Look for Mars and Saturn close together this evening.

july 08

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		[01]	[02]	[03]	[04]	[05]
[06]	[07]	[08]	[09]	[10]	[11]	[12]
[13]	[14]	[15]	[16]	[17]	[18]	[19]
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[27]	[28]	[29]	[30]	[31]		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

01 The Moon passes 8° north of Mercury, 11 A.M. EDT

Mercury reaches greatest western elongation (22°), 2 P.M. EDT

The Moon is at perigee (223,391 miles from Earth), 5:27 P.M. EDT

02 New Moon occurs at 10:19 P.M. EDT

04 Earth is at aphelion (94.5 million miles from the Sun), 4 A.M. EDT

06 The Moon passes 3° south of Mars, 2 P.M. EDT

The Moon passes 3° south of Saturn, 6 P.M. EDT

09 Jupiter reaches opposition, 4 A.M. EDT

10 First Quarter Moon occurs at 12:35 A.M. EDT

11 **Mars passes 0.7° south of Saturn, 2 A.M. EDT; best July 10 for North America**

14 The Moon is at apogee (251,936 miles from Earth), 12:14 A.M. EDT

The Moon passes 0.3° south of Antares, 8 A.M. EDT

17 The Moon passes 3° south of Jupiter, 8 A.M. EDT

18 Full Moon occurs at 3:59 A.M. EDT

20 The Moon passes 0.9° north of Neptune, 9 A.M. EDT

22 The Moon passes 4° north of Uranus, 6 P.M. EDT

25 Last Quarter Moon occurs at 2:42 P.M. EDT

27 Southern Delta Aquarid meteor shower peaks

29 Mercury reaches superior conjunction, 4 P.M. EDT

The Moon is at perigee (226,106 miles from Earth), 7:23 P.M. EDT

31 The Moon passes 0.9° south of Ceres, 1 A.M. EDT

WEB EXTRA For definitions of terms, visit www.Astronomy.com/glossary.

— *Continued from page 40*

opens with the Red Planet lying less than 1° from Regulus, Leo the Lion's brightest star. At magnitude 1.7, Mars is slightly fainter than Regulus (1.3).

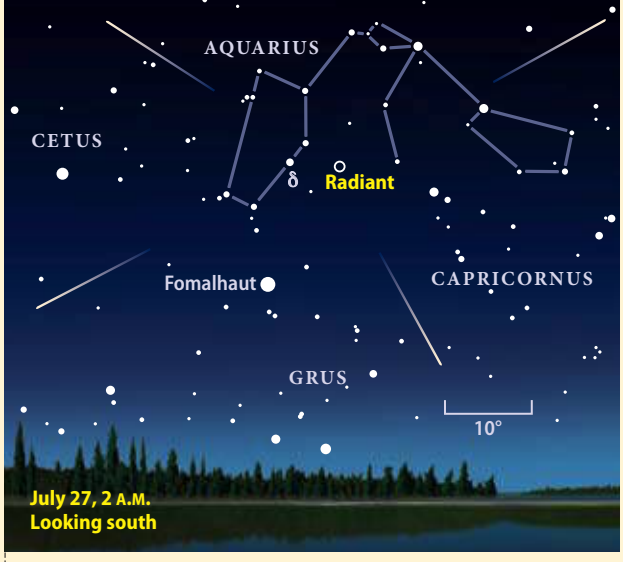
Binoculars will reveal a beautiful color contrast between orange Mars and bluish-white Regulus. Set against twilight's deepening azure sky, this is one of the summer's finest binocular sights. On July 4, enjoy the "red, white, and blue" of Mars, Regulus, and the early evening sky as America celebrates Independence Day.

Each night, Mars pulls farther from Regulus and draws closer to Saturn. On July 5, when the three objects span a straight line 5° long, they're joined by the 3-day-old crescent Moon 5° below Regulus. The next night, the Moon glows nearly 7° to the left of Mars.

Watch over the following 4 nights as Mars edges toward its July 10 conjunction with Saturn. Then, only about 0.7° separates the two worlds and both will be visible in a telescope's low-power field of view. Here's an opportunity to study a new color contrast, but a more subtle one. Compare Mars' orange hue to Saturn's wan, yellowish tint. Can you spot the difference?

Saturn, shining at magnitude 0.8, is nearly a full magnitude brighter than Mars. This is the ringed planet's last month of visibility before it slips into the solar glare. The Sun will hide Saturn for about 2 months before the planet reappears in the morning sky. Saturn remains so low that telescopic viewing won't reveal much in the early evening's unstable air. But take a quick glimpse at the planet's narrowing rings. They'll be even more edge-on when Saturn reappears in the fall.

Jupiter rises in the southeast and dominates the evening. The brilliant orb, shining at magnitude –2.7, never reaches great



LOOK FOR METEORS from Aquarius July 27. Because the constellation lies in the southeastern sky, southern observers will see more meteors than northern skywatchers.

LOOK FOR FIREWORKS FROM AQUARIUS

The summer meteor season begins with a favorable display from the Delta Aquarids. The meteor shower, which is active from mid-July to mid-August, peaks July 27.

This shower favors observers in the southern half of North America. The reason: Southern latitudes place the radiant higher in the sky.

Observing Delta Aquarid meteors just got a little easier. According to the International Meteor Organization, several faint summer showers with reported radiants near Aquarius confused observers. Several new studies, however, indicate the Delta Aquarid radiant is the only real one.

The Delta Aquarid shower produces between 10 and 20 fast — but not especially bright — meteors per hour. The Last Quarter Moon July 25 will create only minor interference with your meteor hunt.

THE MOON'S NOD REVEALS MARGINAL SEAS

Don't resist. Give in to the lunar terminator's spectacular terrain, with chains of half-lit craters and ridges snaking across lava-flooded "seas."

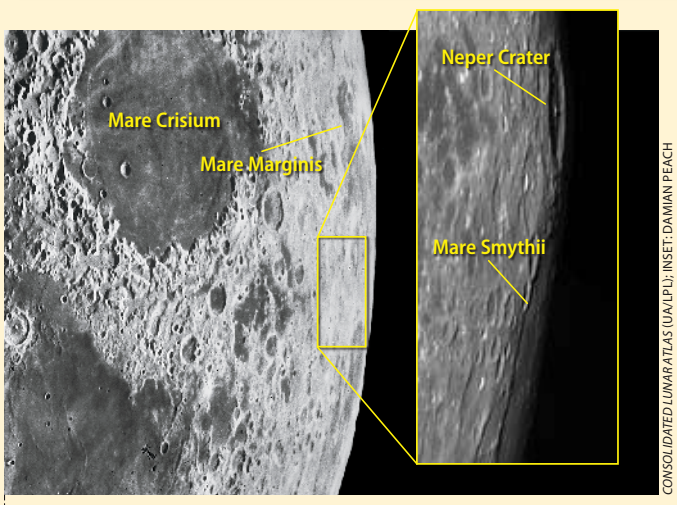
Once you've sated your appetite for fantastic terrain, turn your attention to two medium-gray splotches along the Moon's sunlit side. They are Mare Marginis, named for its spot on the Moon's limb, and, to the south, Mare Smythii. Like other maria, these are impact basins excavated in the Moon's youth.

Between the two "seas" (closer to Marginis) lies dark-floored Neper Crater. Here, an asteroid or comet excavated enough lunar crust that lava flowed upward and flooded the crater's interior. Nearby smaller impacts didn't dig deeply, so they bear more typical crater forms.

By Full Moon July 18, these prominent limb features will disappear. As the lunar month progresses, our perspective changes enough that limb features rotate out of view, a phenomenon astronomers call libration.

Watch for the changes each night you're out. The maria seem to darken as the Sun's elevation increases. On July 5, the rugged back wall of Mare Smythii provides a nice white border that outlines the darker sea.

After the 12th, we see the basin in profile, which causes a noticeable dent along the Moon's limb. Can you see any dark mare here by the 15th?



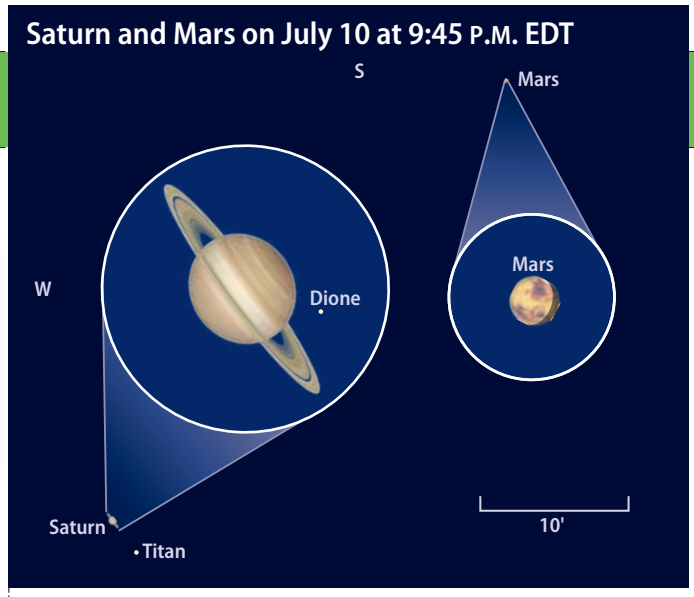
CONSOLIDATED LUNAR ATLAS (UA/LPL); INSET: DAMIAN PEACH

LOOK FOR NEPER CRATER and other limb features in the first half of the month, when a favorable libration brings them into view.

Smythii's walls hide the sea they contain, but because Mare Marginis is much shallower, you may still catch a glimpse of its floor. Neper Crater is in profile by the 15th. The crater's prominent central peak rises beyond the lunar limb like a pimple.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (northwest)	Jupiter (south)	Mercury (east)
Mars (west)	Uranus (east)	Uranus (south)
Saturn (west)	Neptune (southeast)	Neptune (southwest)
Jupiter (southeast)		



ON JULY 10, a low-power eyepiece will let you view Mars and Saturn in the same telescope field. Can you find Titan, Saturn's largest moon? The magnified insets show the planets in detail.

altitude, so the best views occur an hour on either side of midnight, when Jupiter crosses the meridian. The planet lies at the eastern end of Sagittarius the Archer as the month opens. A retrograde path carries it westward during July to a point just south of magnitude 3 Omicron (o) Sagittarii.

Jupiter's disk is full of detail — some of it plainly obvious, like the dark equatorial belts. Spanning 47", Jupiter is so large observers can see features through telescopes of any size.

Martin Ratcliffe *is the author of* State of the Universe 2008 *(Praxis, 2007).* **Alister Ling** *is a meteorologist for Environment Canada.*

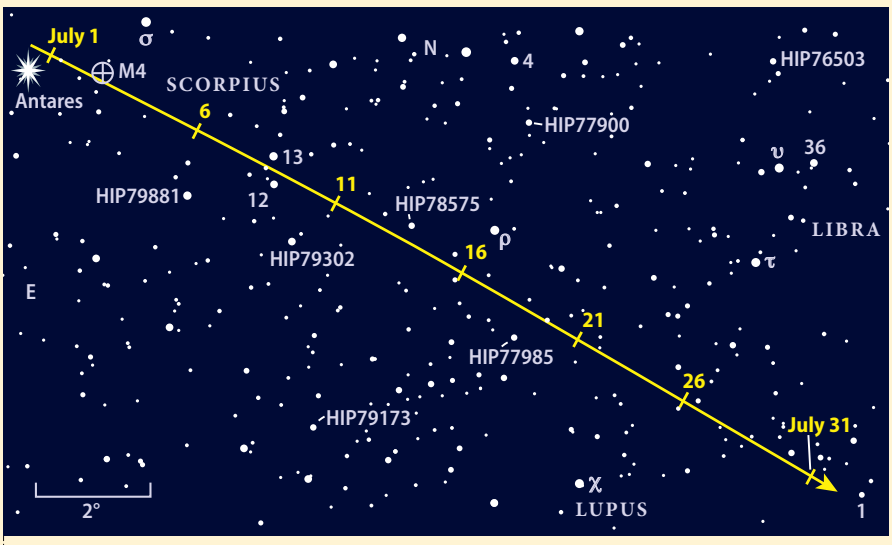
For many decades, the tool of choice for recording observations of the great planet was a sketch pad and pencil. Actually seeing Jupiter's cloud detail is a huge treat, but the fine eddies and spots appear only during brief moments of steadiness in Earth's atmosphere.

It's fair to say most casual observers never see this detail. Often, the planet's disk looks a bit like Jell-O. As turbulent air distorts Jupiter's light, the planet's disk seems to wobble and shake. Viewing with high magnification enhances this effect, so if you can't see much on Jupiter's disk, try using less power.

A webcam or video camera attached to your scope can capture rare steady moments forever. Image-processing software removes rapidly varying detail caused by chaotic turbulence and retains the persistent features on Jupiter's disk. What a great way to spend those cloudy nights!

As Jupiter's moons orbit, they appear to yo-yo east and west of the planet from our perspective. Io, the planet's closest major moon, makes the smallest excursions; it orbits in a couple of days. Europa's swing takes longer, and carries it farther from the planet. Ganymede and Callisto are slower still, taking 8 and 14 days, respectively, per orbit.

Occasionally, due to the particular line of sight, the moons appear close together or gather in unique arrangements. One such alignment occurs in the early morning of July 2. Callisto, Io, and Europa (from north to south) stand in a near-perfect



COMET C/2007 G1 (LINEAR) SPENDS JULY CRUISING through the southern constellations Scorpius and Lupus. The comet's close pass to globular cluster M4 occurs July 2.

CATCH A COMET IN SCORPIUS

Comet C/2007 G1 (LINEAR) is easy to corner but tough to see as July opens. Simply point your scope at the bright globular star cluster M4 (NGC 6121), near the bright star Antares in Scorpius, and you're there.

The challenge, though, is detecting the dirty snowball's feeble glow against the Milky Way's myriad stars and the cluster's extended halo. You'll need dark, country skies and a 10-inch or larger scope to snag this fuzzball.

The comet passes 8' from M4 on the night of the 2nd. Glowing at an integrated magnitude of 11.9, the comet's surface brightness will pale beside M4's distant red giants shining at magnitude 13.4.

Imagers take note. Pictures taken 3 hours apart will make a stereo pair in which the comet floats in front of the cluster.

JUNO CRUISES NEAR M10

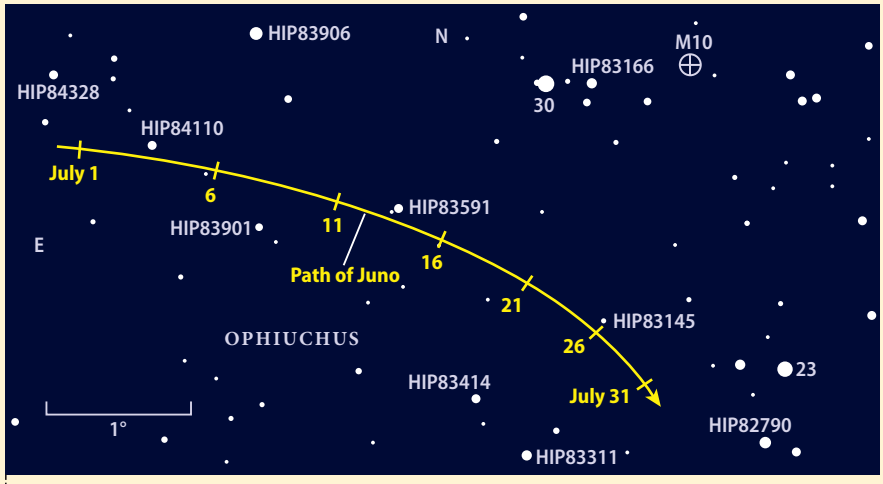
All month long, the main-belt asteroid 3 Juno shares the same finder field as the bright globular cluster M10.

When skies darken in the evening, the large box-shaped constellation Ophiuchus lies a third of the way up the sky in the southeast. Using the all-sky map (center pullout), point your scope to the star that appears under the first "u" in Ophiuchus. This is 4.8-magnitude 30 Oph. From the suburbs, you'll just have to take a stab at its location and center it in your finder.

One degree due west of 30 Oph lies M10. This magnitude 6.6 star ball will be visible in your scope's finder. Its brightest stars are 12th magnitude, and high power with a 6-inch scope will begin to resolve them. From the city, though, you'll need a bigger scope.

With the cluster in view and this chart in hand, slide 2° to 3° southeast from 30 Oph. Gliding only 12' per night, 10.2-magnitude Juno won't give itself away in one observing session. But come back to the same field 3 nights in a row. A simple sketch will reveal the asteroid's displacement against the background stars.

Along Juno's arc, only a few stars shine more brightly than the asteroid. Avoid observing between July 10 and 15, when the Moon brightens the sky.



ASTEROID JUNO runs through Ophiuchus. The space rock lies in the same finder-telescope field as the bright globular cluster M10.

line east of Jupiter around 4 A.M. Eastern Daylight Time (EDT). The trio spans an angle of 20", smaller than Jupiter's disk. Observers west of the Mississippi will best see this arrangement. Jupiter is near the horizon and dawn will be in progress for eastern observers.

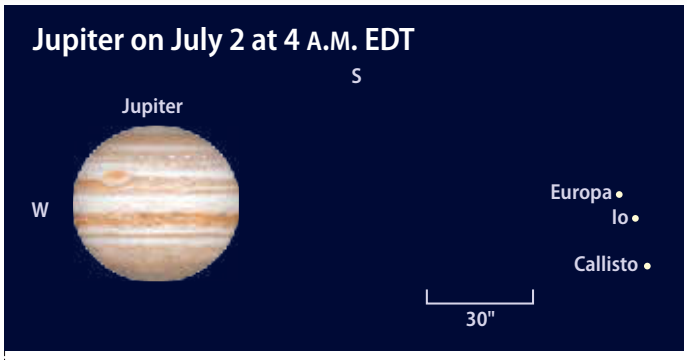
Jumping from the solar system's giant to a planetary dwarf may seem like a big leap, but, in fact, it's a short hop to Jupiter's northwest, where **Pluto** lies. The dwarf planet arrived at opposition June 20 and remains at its best for the year, which isn't saying much. Magnitude 13.9 is the brightest Pluto achieves.

The dwarf planet is located in Sagittarius' extreme northwest corner. Bright guide objects aid in targeting the correct field. Pluto spends the month 1.9° due north of the bright open star cluster M23 (NGC 6494). As July opens, Pluto stands 1° west of the magnitude 6.2 star 6 Sagittarii. At month's end, look for Pluto another 0.7° west of this star.

The two outer giant planets, Uranus and Neptune, are always within reach of binoculars. **Neptune**, which reaches opposition in August, now shines at magnitude 7.9, only slightly fainter than it will be next month. It rises by 10 P.M. local daylight time July 1 and by 8 P.M. at month's end.

To find Neptune, scan your binoculars 2.5° north of Gamma (γ) Capricorni, also known as Nashira. Look for three stars, shining between magnitudes 5 and 6, that lie in roughly a straight line: 42, 44, and 45 Cap. In early July, Neptune lies east of the upper pair, forming a triangle with them. By July 31, the planet has moved to a location almost between the two stars. A telescope will reveal Neptune's bluish disk spanning 2.3".

Uranus, glowing at magnitude 5.8, lies below the famous "Circlet" asterism of Pisces. Technically, the planet is a naked-eye target, but it takes keen eyesight and clear, transparent skies to spot Uranus without optical aid. Binoculars make the task easier, but correctly identifying Uranus in a field of stars takes a little effort.



CHECK OUT JUPITER in the wee hours July 2 for a moon-alignment treat with Europa, Io, and Callisto. Changes in configurations like this let you glimpse the moons' orbital motions in a few minutes.

The easiest way to find Uranus is to begin with Phi (ϕ) Aquarii. This magnitude 4.2 star lies south of a line extending down the right side of the Square of Pegasus. A trio of 6th-magnitude stars lies 5° northeast of Phi, and Uranus lies near them. The planet's retrograde path carries it from about a Moon's width east of the trio as July opens to a point close to the trio's northernmost star by month's end.

Mercury, the innermost planet, puts on a fine morning show during July's first half. Mercury reaches its greatest angle west of the Sun July 1, when Mercury lies 22° away. A thin, 27-day-old waning crescent Moon rises first, just north of due east, shortly after 3 A.M. local daylight time. About 20 minutes later comes Aldebaran, and 20 minutes after that comes 0.4-magnitude Mercury.

By July 7, Mercury lies half a Moon-width from Zeta (ζ) Tauri, the Bull's southern horn. Zeta will be hard to spot in brightening twilight, but Mercury will be an easy magnitude –0.2. Mercury drops out of visibility quickly after midmonth. The innermost planet reaches superior conjunction with the Sun July 29.

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Finesse: 17

Refocus Lens
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Second Surface: <0.2% Anti-reflection Coating

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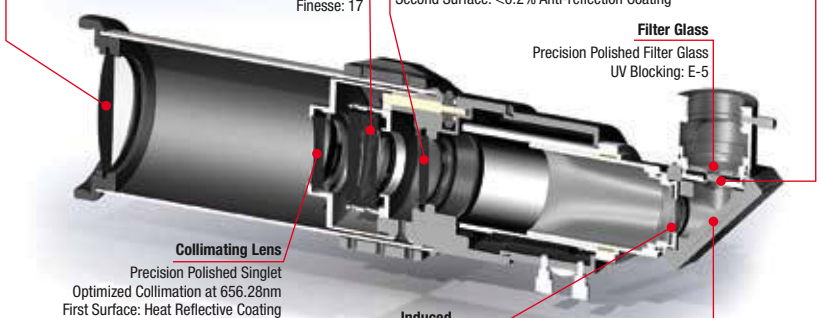

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The 24 lectures in **Superstring Theory: The DNA of Reality** incorporate Dr. Gates's matchless set of graphics, which introduce you to such concepts as hidden dimensions, dark matter, sizzling black holes, and a theory-destroying monster called the tachyon.

Spaghetti Strands

The essence of string theory is that the smallest, most fundamental objects in the universe are not little balls, knocking around like billiards, as had been thought for about 2,000 years. Instead, these small objects are super-microscopic filaments—like tiny strands of spaghetti—whose different vibrational modes produce the multitude of particles that are observed in the laboratory.

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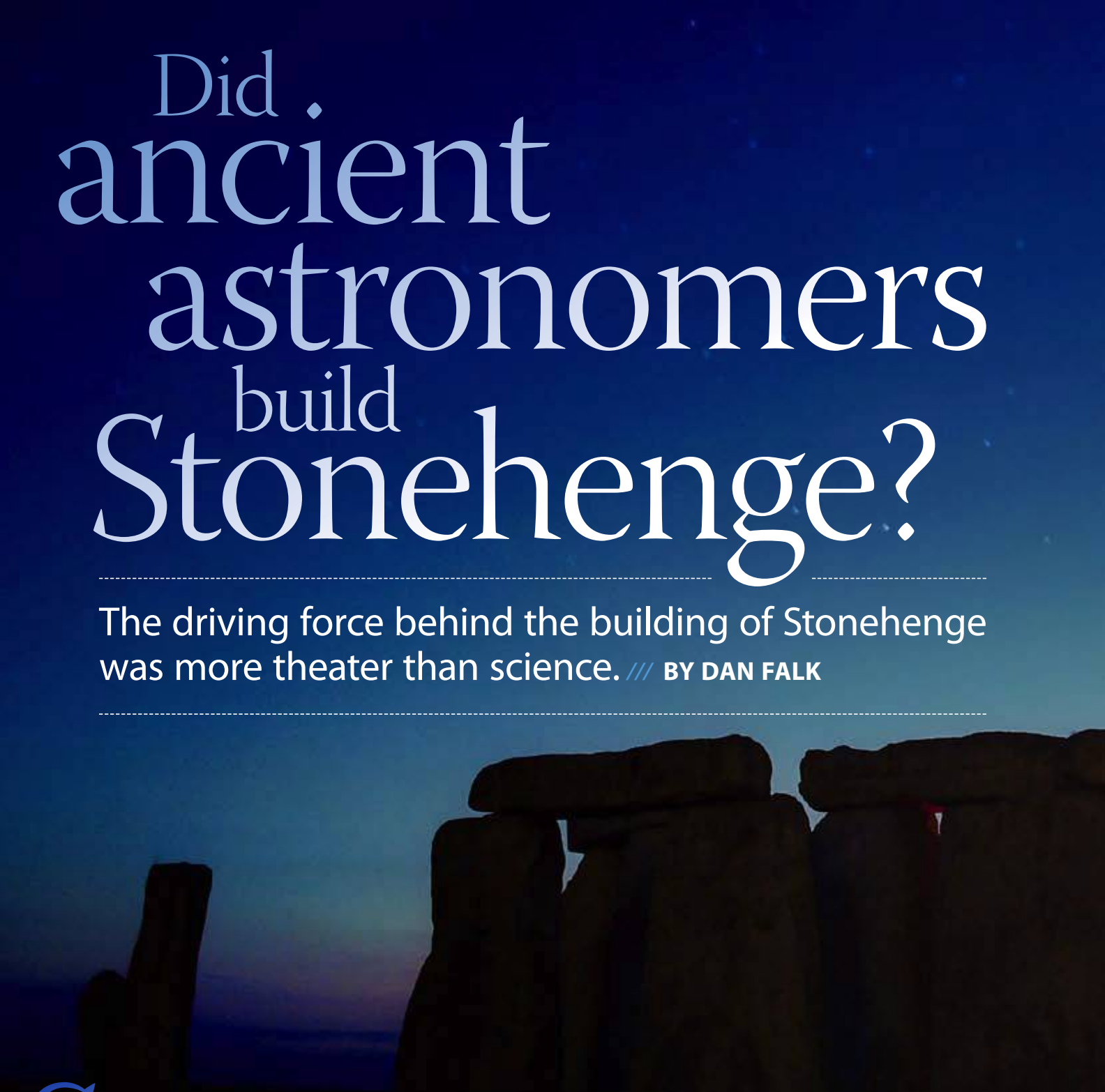
Did ancient astronomers build Stonehenge?

The driving force behind the building of Stonehenge was more theater than science. /// BY DAN FALK



Some 5,000 years ago, ancient Britons erected a vast circular embankment between the low hills of England's Salisbury Plain. A few centuries later, after several spurts of additional construction, a central circle of 40-ton upright stones stood capped by 10-ton horizontal "lintels." This is Stonehenge, one of the greatest achievements of prehistoric Europeans.

Why did ancient peoples put so much effort — some millions of work-hours — into this and other, similar constructions? Stonehenge and its brethren clearly were important. They often show evidence of astronomical alignments. But how many of these alignments were deliberately designed into the monuments? Were they, in any meaningful sense, Stone Age observatories? What answers scientists can give to these questions haven't come easily.

Guidebooks warn first-time visitors to keep their expectations in check when they visit Stonehenge. A towering monument in our imaginations, the stones often seem surprisingly small in real life.

ENGLAND'S STONEHENGE, seen here with Comet Hale-Bopp in 1997, is the most famous Neolithic monument, but it's by no means unique. What was its purpose: cosmic calendar, solar temple, theatrical set-piece? Most archaeologists now think Stonehenge and structures like it were, to some degree, all of these things. PHILIP PERKINS/ASTROCRUISE.COM

Stonehenge in its prime

NEOLITHIC BUILDERS started construction at Stonehenge in 3000 B.C. The monument began as a circular ditch, an embankment, and 56 shallow pits that once held timber posts.

During the final phase, which lasted 1,000 years, the building material changed from wood to stone. In 2600 B.C., workers placed 80 bluestones transported from Wales into a central crescent.

Next, they added the sarsen stone circle and the horseshoe of trilithons, followed by outlying structures. Stonehenge reached its final form, shown in this reconstruction, by 1600 B.C.

ASTRONOMY: JAY SMITH

"Some days it almost shrinks into the landscape; other days it just stands out," says David Batchelor, an archaeologist with English Heritage, the agency responsible for protecting and promoting the monument. Batchelor, who showed me around Stonehenge early one spring morning, tells me the weather conditions dictate how imposing the stones appear.

I suspect the most important factor is simply one's distance. From the low rope barrier that marks the closest approach for most visitors, the stones do, indeed, seem less than spectacular.

Earthmoving

Only when one comes right up to the monument's massive vertical stones does its magnitude really hit home. Batchelor points to the outer circle of large upright stones, the so-called sarsen circle. The builders of Stonehenge, he says, moved these stones from quarries up to 25 miles (40 kilometers) away.

Just inside the sarsen circle is a smaller concentric ring of upright "bluestones." "These are the ones that come from the Preseli Mountains in southwest Wales," Batchelor explains, referring to a mountain range more than 150 miles (240 km) away. One can only imagine the effort required to drag so many massive stones such an enormous distance.

While Stonehenge is the best known and, perhaps, the most impressive Neolithic monument, it's hardly alone. Hundreds of equally ancient stone structures, known as "megaliths," occur across Britain, Ireland, and northwestern Europe. A few sites, such as nearby Avebury and Callanish in northwestern Scotland, rival Stonehenge in size and sophistication.

For centuries, scholars have speculated on the purpose of these ancient structures. Perhaps the most commonly expounded theory — and the one that has taken root most deeply in the popular imagination — is the notion that these monuments were astronomical observatories used to help track the motions of the Sun, Moon, and stars. This claim always has been controversial. It's enlightening to compare the rather cautious reflections of archaeologists and archaeoastronomers today with the often wild speculations of earlier decades.

Trilithons and bluestones

Let's start with Stonehenge itself. The monument's largest stones are arranged in an arc at the very center. They consist of five enormous "trilithons," each made from two

massive uprights and capped with a horizontal lintel. They're laid out like a horseshoe, with the axis of symmetry lying along a southwest-northeast line.

That axis, astronomers long have recognized, aligns with the spot on the northeastern horizon where the Sun rises on the longest day of the year — the summer solstice. The axis also passes by an outlying rock — the so-called "heel stone" — to the monument's northeast.

One can imagine a Neolithic observer, watching from the center of Stonehenge, using the heel stone as a kind of gunsight to track the rising Sun on the summer solstice. Likewise, an observer at the heel stone could have watched the Sun set over the monument on the winter solstice.

As Colgate University archaeoastronomer Anthony Aveni puts it, Stonehenge probably was "a Sun temple from its very inception." This basic alignment seems beyond dispute. But Batchelor says scholars continue to debate whether the monument's builders worshipped at midsummer, midwinter, or both.

The orientations of other nearby structures from the same period, many of which also appear to display a solar alignment, offer support for the interpretation of Stonehenge as a Sun temple. Even the area's older structures, such as the "long barrow" tombs that pepper the surrounding countryside, typically display a solar orientation, albeit a less precise one. Most align east-west, with the entrance pointing roughly east. But the actual angles cover such a wide range that some scholars suggest they reflect a lunar, rather than a solar, orientation.

A light in the dark

The British Isles' oldest megalithic structure shows an unambiguous solar orientation. This is the "passage tomb" of Newgrange in County Meath, Ireland, a structure that dates from about 3100 B.C.

From the outside, Newgrange looks like a wide, low, circular earthen mound. A narrow passageway stretches some 80 feet (24 meters) inside. At the tomb's far end, three small alcoves branch off from the main passage. On the morning of the winter solstice, sunlight streams through a small opening above the main entrance and illuminates the back of the tomb.

The chances of this solstice alignment being accidental are minute, says astronomer Tom Ray of the Dublin Institute for

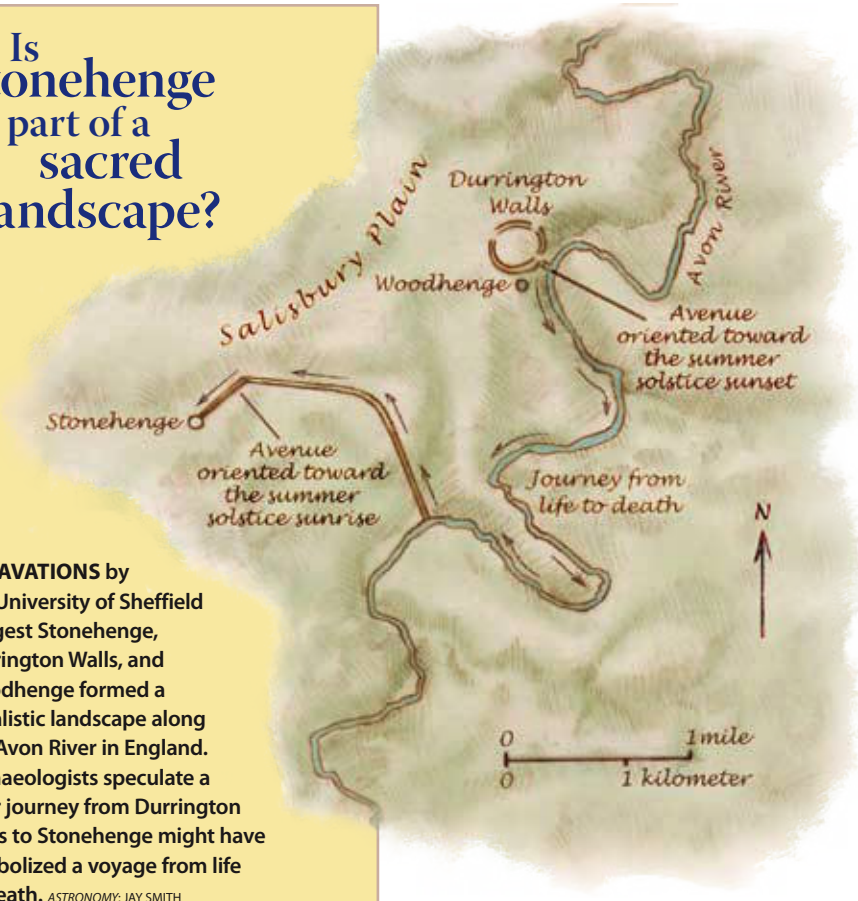
THE STONES TODAY remain as enigmatic as ever. Two other circular earthworks, or henges, lie nearby: Durrington Walls and Woodhenge. In 2006, the University of Sheffield's Stonehenge Riverside Project found the remains of a village near Durrington Walls dated to 2500 B.C. — about when Stonehenge's bluestones were placed. SKYSCAN BALLOON PHOTOGRAPHY

A world of stone circles

THIS MAP SHOWS the locations of Stonehenge and other well known Neolithic monuments.

ASTRONOMY: JAY SMITH; PHOTOGRAPHS: DAN FALK

Is Stonehenge part of a sacred landscape?



EXCAVATIONS by the University of Sheffield suggest Stonehenge, Durrington Walls, and Woodhenge formed a ritualistic landscape along the Avon River in England. Archaeologists speculate a river journey from Durrington Walls to Stonehenge might have symbolized a voyage from life to death. *ASTRONOMY:* JAY SMITH

Advanced Studies. He investigated Newgrange's geometry in the 1980s. Today, on the solstice, several minutes pass between sunrise and the first penetration of light into the tomb. This delay is the result of changes in Earth's axial tilt over the past 5,000 years. When Newgrange was built, Ray explains, the summer-solstice Sun would light the passageway exactly at dawn. There's no question the solar alignment was the intention of its builders, he says.

But unambiguous alignments, like the solstice axes at Newgrange and Stonehenge, are the exception rather than the rule. Most other claims of astronomical alignments — especially those involving the Moon or the stars — are more problematic.

Some scholars have argued that the trilithons at Stonehenge could be used not only to track the Sun, but also to monitor significant moonrises and moonsets throughout the year. That's certainly possible — such claims hardly can be disproven — but the evidence is much less clear than with the solstices.

Dan Falk *is a science journalist based in Toronto. His latest book,* In Search of Time: The Science of a Curious Dimension*, will be published by St. Martin's Press this fall.*

Stone Age astronomers?

Other scholars point to the ring of 56 chalk-filled holes (called Aubrey holes) at Stonehenge, just inside the outer embankment, which archaeologists believe once held upright wooden posts. A few eager writers have claimed the posts served as an analog calculator, allowing Neolithic priests to predict eclipses.

The idea that Stonehenge's builders could use the monument to predict eclipses has fallen in and out of fashion several times over the last few decades. In general, though, archaeologists treat the notion with far more skepticism today than in the 1960s and '70s. Then, a few authors went to great lengths to expound on astronomical uses for Stonehenge and other Neolithic monuments.

Some scholars express downright embarrassment when they think back to the runaway enthusiasm for "ancient astronomers" in those days. Archaeologist and archaeoastronomer Clive Ruggles, now retired from the University of Leicester, wrote that it "forms one of the most notorious examples known to archeologists of an age recreating the past in its own image." He added that there is "no reason whatsoever to suppose that at any stage the site functioned as an astronomical observatory — at least in any sense that would be meaningful to a modern astronomer."

The problem is largely one of design versus chance. Certain stones may be aligned with certain astronomical phenomena, but what evidence is there that such alignments are more than mere flukes? With enough stones and enough celestial "targets" — the rising or setting position of a particular bright star, for example — alignments become inevitable. As archaeologist Aubrey Burl, retired from Hull College of Higher Education, wrote: "Statistically, the odds are in favour of a good celestial sight-line occurring fortuitously in almost any circle."

Some of the more extravagant claims involve Callanish, sometimes called "The Stonehenge of Scotland." Dramatically situated on a cliff on the Isle of Lewis in the Outer Hebrides, the location may have been chosen "because it allows the viewing of a dramatic interaction between the landscape and the movements of the Moon," says archaeologist Patrick Ashmore of Historic Scotland, the agency responsible for the monument. He believes people gathered at the site at intervals of 18½ years, when the Moon would have reached its southernmost sky position.

Other scholars suggest that one of the monument's rows aligns with the rising of the Pleiades star cluster (M45). Remarkably, that phenomenon is mentioned by the Greek historian Diodorus, in reference to a "spherical temple" somewhere in Britain. But, as usual, the evidence is ambiguous: There's no way to know if Diodorus was referring to Callanish, and no proof the Pleiades alignment is anything more than a geometric quirk.

Consider the Drombeg stone circle in County Cork, Ireland. As with Stonehenge, the circle's main axis often is claimed to be aligned with the Sun's solstice position. Yet, southwest Ireland hosts some 50 stone circles, and none of them shares this alignment. If astronomy was guiding the builders' thinking, why is the solstice alignment seen only at Drombeg?

No doubt, the Neolithic builders who erected Stonehenge and the other great megalithic monuments were conscious of

THE CREATORS of Stonehenge left no written records, so we may never know why it and similar structures played such an important role for millennia. Perhaps by embodying aspects of both earth and sky, the monuments served as symbolic links between life and death. DAN FALK

— and may have followed closely — the movements of heavenly bodies. But it is not at all clear that astronomy was their foremost concern in placing the stones.

A monument for the ages

Archaeologist Timothy Darvill of the University of Bournemouth acknowledges that the orientation of Stonehenge's main axis gave the structure "some sort of astronomical role in the lives of its builders." But he's more interested in the relationship between the monument and the surrounding landscape. The design, he says, may be largely symbolic, inspired as much by the "sacred geography" of the region as by the sky.

Stonehenge was almost certainly a ceremonial center — a place where men and women gathered to pay tribute to their ancestors. The area's many burials suggest this. Neolithic peoples also may have paused to honor the Sun and Moon, and to mark the seasons. Such activities involved the motions of heavenly bodies, but did not require precise observations.

It's difficult to disentangle religious observance from cosmology, especially when celestial bodies likely were objects of devotion. But Aveni suggests it isn't necessary. Stonehenge, he writes, is best thought of "as a place of social gathering, of religious assembly, as a cultic center, as a place of fortified habitations, a celestial temple, and observatory."

All of these definitions crosscut one another. Perhaps, at different times, the ancient skywatchers stressed some meanings more than others. After all, this was a cultural center that retained its importance for millennia. Aveni agrees they may well have tracked celestial bodies. But he adds: "I am convinced that if Stonehenge has anything to do with lunisolar astronomy, the association between its Neolithic builders and the sky is more closely allied with theater than with exact science."

Unfortunately, the builders of Stonehenge had no written language. No Rosetta Stone will fill in the blanks of their story. Visitors to Stonehenge and the other Neolithic monuments will continue to marvel at the stones, knowing that a final answer probably never will come.

"It's amazing," says Batchelor as we leave the inner circle. "I've worked here for 15 years, and I still get a tingle when I come inside. I can't define it, but there is something very special here." A

WEB EXTRA Listen to Dan Falk discuss his new book, *In Search of Time*, at www.Astronomy.com/toc.

Nearest star could host exo-Earth

NEAREST NEIGHBOR

Q: Could nearby stars Alpha Centauri A and B harbor earthlike planets in stable, circular orbits? — **CHUCK WEBER,** RENO, NEVADA

A: According to two groups of planet-formation theorists, the answer is yes. Although no evidence for such planets has yet surfaced, astronomers continue to search the system for new worlds.

Alpha Centauri, our nearest stellar neighbor, lies some 4.37 light-years (about 277,600 times the average Sun-Earth distance) away in the constellation Centaurus. The system contains three stars. The brightest member, A, is a Sun-like, G-type star. The B component is a slightly smaller, cooler, K-type star. They orbit one another every 79.9 years and, at closest approach, lie only a billion miles (1.6 billion kilometers) apart. That's about 15 percent farther than Saturn's distance from the Sun.

The system's third star, Proxima Centauri, is so named because it's the closest member to us. However, Proxima orbits the system at hundreds of times the distance separating the other members.

Because the two Sun-like stars periodically pass so close, some astronomers thought the gravity of one star might preclude the formation of planets around the other. That turns out not to be the case. Studies show that any earthlike planets within 186 million miles (300 million km, or 2 AU) of either the A or B star will remain on stable, circular paths. — **ALAN P. BOSS,** CARNEGIE INSTITUTION OF WASHINGTON

YOUNG PLANETS

Q: What is a planemo? — **SYLVIA MONTGOMERY,** ROCKVILLE, MARYLAND

A: A planemo is a planetary-mass object that never undergoes fusion, unlike stars. Planemos form when gas and dust collapse, but planemos are not massive enough for nuclear fusion ever to occur in their cores. These objects are more massive than irregularly shaped asteroids but less massive than brown dwarfs, which can fuse deuterium when young. A planemo that orbits a star is called a planet.

Astronomers first detected isolated planemos in about 2000. They thought the objects were either young planets booted out of their solar systems or small stars that never grew massive enough to ignite.

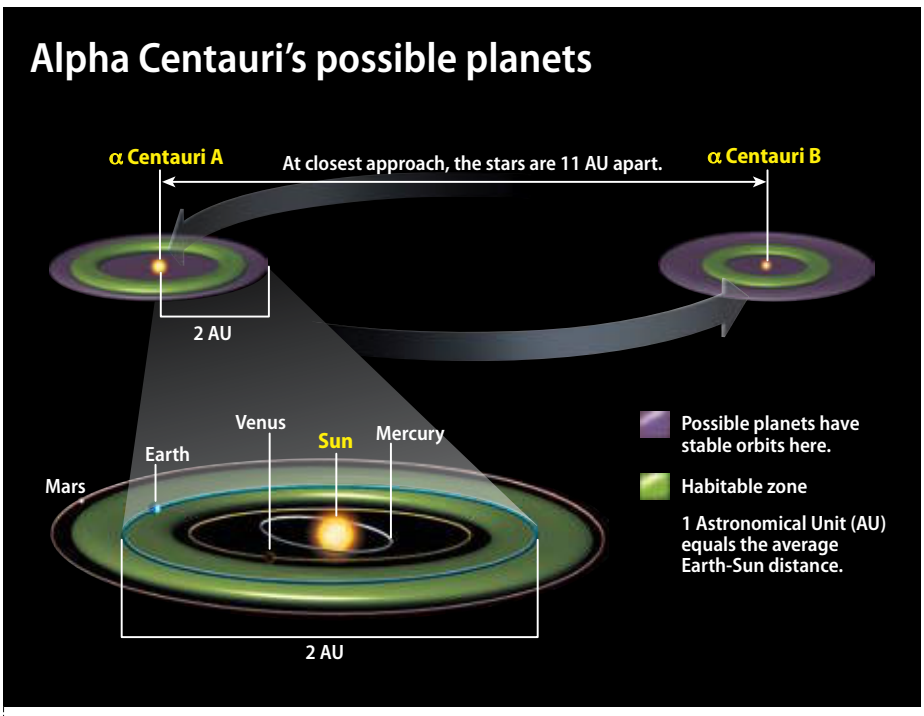
In November 2007, Alexander Scholz of the University of St. Andrews in Scotland and Ray Jayawardhana at the University of Toronto reported 18 planemos in the Sigma Orionis star cluster. The cluster is only 3 million years old, an appropriate length of time for rocky, terrestrial, earthlike planets to have formed there. — **DANIEL PENDICK,** ASSOCIATE EDITOR

NAMING COMETS

Q: How are comets named? — **ALICE METCALF,** KANSAS CITY, MISSOURI

A: Comets can be named for up to three independent discoverers. Increasingly, those discoverers are not individuals, but automated observatories or solar-observing satellites like the NASA/ESA Solar and Heliospheric Observatory.

That poses a problem. Discoverers' names don't uniquely identify a comet, so **astronomers also give each comet a unique catalog number.** This starts with a one-letter prefix, usually a C for "comet" or a P for "periodic," followed by the discovery year and a letter that indicates which half of the month the discovery occurred. "A" represents January 1 though 15, "B" is January 16 through 31, and so on. Next comes a number representing the order of discovery during each half-month period.



TERRESTRIAL PLANETS may orbit the central suns of the Alpha Centauri system. Planet-formation models show that, despite the stars' close proximity, Alpha Centauri A and B could host earthlike planets. *ASTRONOMY:* ROEN KELLY, AFTER KEN CROSWELL

Here's how all this comes together. Let's take Comet McNaught, the first comet discovered in the first half of August 2006. Its designation: C/2006 P1.

When a comet's return through our solar system becomes well established, either through a recovery or by observing a second passage past the Sun, astronomers classify the comet as periodic. They then add a unique number to the prefix. So, Comet Halley, the first comet whose return was identified, is known as 1P/Halley. — **FRANCIS REDDY,** SENIOR EDITOR

IMPACT DATA

Q: Where can I get information about impact sites on Earth? — BETTY SMITH, WILLIAMSON, WEST VIRGINIA

A: The Earth Impact Database and the Suspected Earth Impact Sites list are good web sources for information on terrestrial impact sites. The Earth Impact Database (www.unb.ca/passc/ImpactDatabase), maintained by the Planetary and Space Science Centre (PASSC) at the University of New Brunswick, provides detailed pages on 174 craters that meet its strict criteria for inclusion.

David Rajmon at Shell Inc. in Houston maintains a list of Suspected Earth Impact Sites (web.eps.utk.edu/ifsg.htm) designed to complement the Earth Impact Database. Rajmon's list ranks impact sites as confirmed (4), probable (114), possible (450), improbable (18), and rejected (73) — all based on reports published in scientific journals. — **FRANCIS REDDY,** SENIOR EDITOR

METEOR CRATER resulted about 50,000 years ago when a 50-meter-wide nickel-iron meteorite struck Earth in what is now northern Arizona. D. RODDY (USGS)/LPI

BLACK HOLE FUTURE

Q: Does a black hole stay a black hole for life? — ALEXANDER LAWSON, SPRINGFIELD, ILLINOIS

A: Once a black hole, always a black hole. The only significant change a black hole experiences is growth when it absorbs mass — from a nearby star, from gas at the center of a galaxy, or by merging with another black hole.

A black hole can, in principle, evaporate by emitting radiation, a process first recognized by Stephen Hawking at England's University of Cambridge. Quantum mechanical effects cause black holes to emit radiation. This removes energy, and Einstein's famous $E = mc^2$ equates this lost energy to a decrease in mass.

Hawking radiation is extremely weak. A black hole of the Sun's mass would take 10^{67} years — 1 followed by 67 zeros — to evaporate. That's much longer than the universe's 13,700,000,000-year age. Heavier black holes evaporate even more slowly. The Milky Way's central black hole, which has a mass between 3 and 4 million Suns, would take more than a billion billion times longer to disappear.

Because Hawking radiation is so weak, as a matter of practice it's irrelevant in astronomy. Any infalling matter or radiation easily overwhelms this loss. Even photons from the cosmic microwave background add more mass to a black hole than Hawking radiation takes away. — **SCOTT A. HUGHES,** MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS

IN THE KNOW

BROWN DWARF
A gaseous object that forms like a star but lacks the necessary mass to sustain nuclear fusion at its core; a body intermediate in mass between a star and planet.

PLANET
A body that orbits a star, does not undergo nuclear fusion in its core, contains enough mass for its own gravity to shape it into a sphere, and has cleared smaller bodies from its orbital path.

HAWKING RADIATION
The emission of radiation by a black hole due to quantum mechanical effects.

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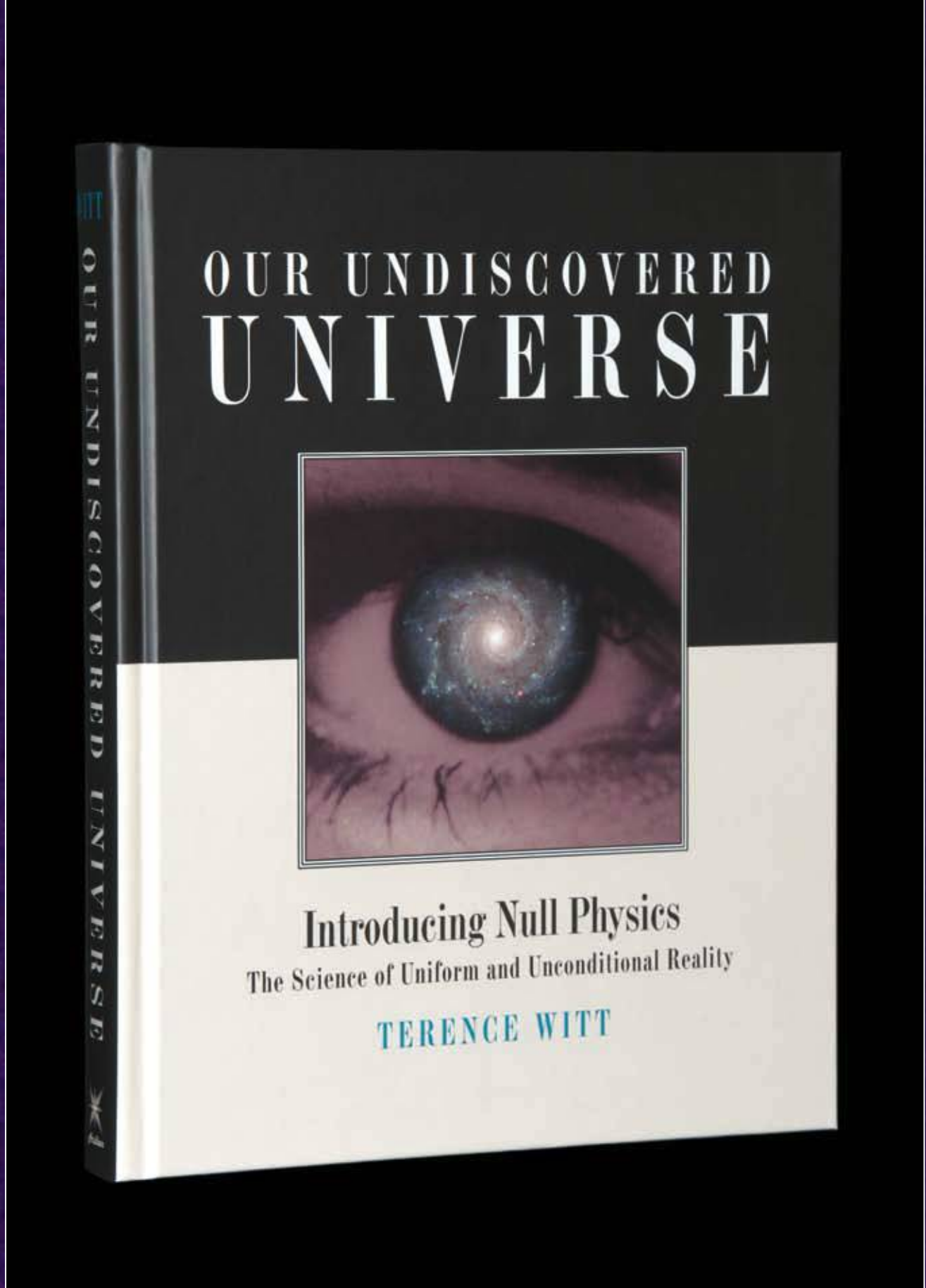
OUR UNDISCOVERED UNIVERSE
OUR UNDISCOVERED UNIVERSE
Introducing Null Physics
The Science of Uniform and Unconditional Reality
TERENCE WITT

Theoretical physics has been hopelessly stalled for over 30 years. Moribund. Ossified. The Standard Model of particle physics uses over 20 ad hoc constants, and no one knows why they are necessary or why they have the values they do. Quantum physics and general relativity remain utterly incompatible. Cosmologists haven't the foggiest idea what could have caused the Big Bang or what, if anything, came before it. And finally, after over 30 years of effort, string theory hasn't even achieved the status of *science*.

There is a very simple reason for this catastrophic, intractable mess. Theorists stopped asking *why* a long time ago. Without the *why*, the search for mathematical symmetries becomes numerology, not science. No telescope or particle accelerator, regardless of its size, is going to tell us *why* the universe is the way it is. When the *why*'s remain unanswered, there is no understanding. When there is no understanding, there is no progress. But this sad situation is about to change forever.

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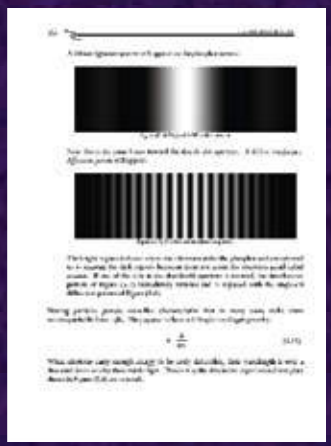
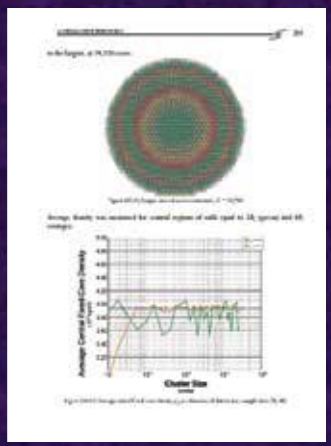
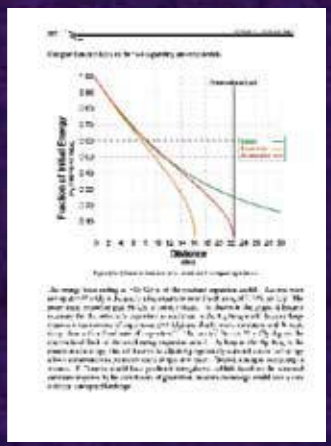
- A black hole's peak density is 1.2(10)^{19} kg/m^3, about 60 times more dense than atomic nuclei.

Welcome to 21st century physics

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What we saw through a 30-inch telescope under an inky black sky blew our minds. /// **BY MICHAEL E. BAKICH**

Observing the way it was meant to be

Nothing is better than observing

under a dark, clear, steady sky. Wait, one thing's better — observing that sky through a large scope. In February, I had the opportunity to do just that under the pristine conditions at Arizona Sky Village (ASV), located in Portal, Arizona. As a guest of real-estate developer Eugene Turner, I had 2 nights with Turner's superb 30-inch Starmaster telescope.

The 30-inch is a high-quality Newtonian reflector on a Dobsonian mount. I'd used this telescope one year earlier, with *Astronomy*'s editor, David J. Eicher. We observed many celestial wonders in Orion and the rest of the winter sky. One of us would call out an object, and Turner would direct the telescope toward it.

The bigger, the better

Aperture, the size of a telescope's main lens or mirror, offers two advantages: light-gathering power and resolution.

The more light a telescope gathers, the brighter the image will appear and the more detail you'll see. If you double the aperture, you capture 4 times as much light. So, an 8-inch telescope gathers 4 times as much light as a 4-inch.

But there's another advantage to all the light a large scope collects. The object may appear bright enough to trigger your eyes' color receptors. A planetary nebula that looks whitish-gray through a 6-inch telescope may show shades of aqua or blue through a 12-inch instrument.

The other factor influenced by increasing aperture is resolution, the ability to see fine detail. In the simplest formula that defines a telescope's resolution, called Dawes' limit, the resolution (in arcseconds) equals 4.56 divided by the telescope's aperture in inches. So a 4-inch scope has a resolution of 1.14" and an 8-inch scope's resolution is 0.57". The quality of Earth's turbulent atmosphere over a particular site determines a telescope's true resolution, but a large scope starts with a bigger advantage.

THE 30-INCH STARMASTER Dobsonian-mounted reflector at Arizona Sky Village takes advantage of the dark, steady sky there. All observations were through this scope. EUGENE TURNER

THE GHOST OF JUPITER (NGC 3242) is a small object. Its bright inner sphere measures only 25" across. Seeing the 40"-wide outer halo and fine details requires a large telescope and high magnification.
ADAM BLOCK/NOAO/AURA/NSF

The man with a plan

Not wanting to waste a moment of such high-quality observing time, I prepared an observing list of 30 objects. During the 2-night adventure, I observed every one of my targets, plus many more.

Because it was February, sky objects naturally divided into two classes. In the early evening, the winter Milky Way with its nebulae and bright star clusters dominated the view. After midnight, the region 19th-century observers called the "realm of the nebulae" rose into view.

Astronomers now know these "nebulae" are galaxies. Traditionally, the three

THE CIGAR GALAXY (M82) in Ursa Major is a great object for 6-inch or larger telescopes. Through a 30-inch scope at 736x, however, it ranks as a spectacular sight. TONY AND DAPHNE HALLAS

THE HORSEHEAD NEBULA (B33) in Orion may pose a challenge to 12-inch and smaller telescopes, but ASV's 30-inch Starmaster reflector rendered it immediately visible. R. JAY GABANY

stars of the Spring Triangle asterism — Arcturus (Alpha [α] Boötis), Spica (Alpha Virginis), and Denebola (Beta [β] Leonis) — mark the realm's boundaries.

Galaxies are the toughest class of celestial objects to observe. Most of them are faint and large. While planets and planetary nebulae occupy only arcseconds of sky, galaxies stretch for arcminutes. Galaxies' sizes give most of them low surface brightnesses. To see detail in them, you must use at least an 8-inch telescope.

Low surface brightness means you must avoid light pollution. For galaxy-watching, even a large telescope proves useless under an urban sky. And, because galaxies contain all kinds of objects, their light isn't confined to one spectral zone. So any type of filter actually worsens the view.

Michael E. Bakich *is a senior editor of* Astronomy *who has a severe case of aperture fever. He'll own a giant telescope one day.*

Luckily, ASV met both criteria for successful galaxy observing: Turner's scope offered 30 inches of aperture, and the sky is among the darkest in North America.

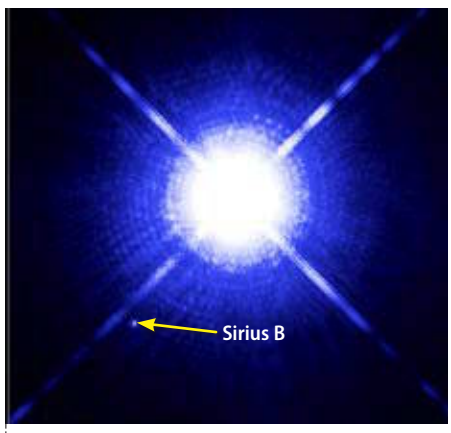
Hello, old friends

Although I was understandably eager to begin, it wasn't anticipation that led me out during evening twilight — it was practicality. For in the south-southeastern sky sat one of amateur astronomy's all-time observing challenges: Sirius B.

This white-dwarf star shines 10,000 times fainter than Sirius and currently lies only 8" from its brilliant companion. Observing this pair during twilight cuts Sirius A's glare. I spotted the B star easily, and several in our group (a mix of about a dozen ASV residents and visitors) saw it a couple of hours later when Sirius sat highest in the southern sky.

Next on the list was the often-elusive Horsehead Nebula (B33). When I asked Turner to point the 30-inch toward it, I heard a few gasps, and several other people said, "I've never seen that."

"Tonight's your lucky night," I thought, smiling. Then, I was at the eyepiece enjoying my best view ever of this "challenge" object: It filled about one-third of the field of view, with the horse's nose pointing down. It was so easy to see that, the next night, Dave Eicher saw it after coming outside from an illuminated room — before his eyes had a chance to dark-adapt!



SIRIUS B currently lies 8" from its much brighter companion, the largest separation in many years. Spotting it requires high power, a steady sky, and a high-quality telescope. NASA/ESA/H. BOND (STScI)/M. BARSTOW (UNIV. OF LEICESTER)

As I checked off other faint wonders, I felt the need to share a few bright objects. I

REFLECTION NEBULA M78 in Orion presents a scalloped appearance through a large telescope. You can't see its gas in motion, but you can see the result of that movement. DANIEL VERSCHATSE

chose open cluster M46 (with embedded planetary nebula NGC 2438) and the Ghost of Jupiter (NGC 3242).

The Ghost always has been one of my favorite planetary nebulae. But where I had seen only a bluish ball with scant detail before, the view through the 30-inch left me speechless. At just 184x, a large sphere occupied half the field of view. Inside lay another, brighter sphere, with extensions like those of a barred spiral galaxy. In the middle, the central star blazed away.

Near the end of the first night, another observer asked if we could take a look at the Cigar Galaxy (M82) in Ursa Major. Turner swung the scope around, and there sat the starburst galaxy in all its glory.

After viewing it at 105x, my friends started using eyepieces that gave more and more magnification. Usually, this activity stops when the seeing (a measure of the atmosphere's steadiness) begins to degrade the image. I guess I forgot where we were, however, because they ran out of eyepieces before we reached the sky's limit.

At a final magnification of 736x, we had to pan across the galaxy. Each subsequent magnification revealed some new detail in this celestial wonder.

Night two was filled with more terrific objects. For many in the group, the highlight was reflection nebula M78 in Orion.

This bright (magnitude 8.3) object easily allowed us to use 400x and above and showed structure I'd never seen through other telescopes. The large cloud seemed to wash over the small features, giving the object a three-dimensional appearance. Amazing!

Aim big

This two-night, big-scope session ranks as one of my all-time best observing runs. The dark, steady sky above Arizona Sky Village, Turner's hospitality, other excited observers, and the 30-inch scope resulted in two nights I'll never forget. Next time someone asks you why you want a bigger telescope, hand them this article. A

THE ESKIMO NEBULA in Gemini is small, less than 1' across, so you'll need high magnification to see its details. One advantage of a large scope is that it collects lots of light, making the magnified image brighter. PETER AND SUZIE ERICKSON/ADAM BLOCK/NOAO/AURA/NSF

VOYAGE TO DARKNESS

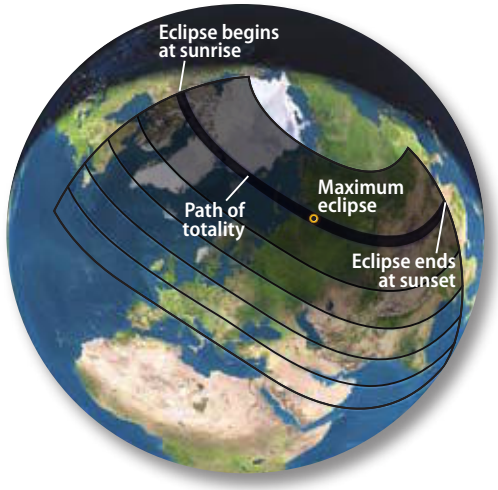
On August 1, the Moon will cover the Sun's face for a fortunate few.

/// BY MICHAEL E. BAKICH

Get ready for summer's total solar eclipse

On August 1, a lineup of three celestial

bodies will turn daytime into dusk during the 21st century's sixth total solar eclipse. As the Moon slowly covers the Sun's face — then hides it for as much as 2½ minutes — where you are will determine how much of this event you'll see.



THE AUGUST 1 total solar eclipse begins in Canada, moves through Greenland and Russia, and ends in China. ECLIPSE FIGURE COURTESY OF FRED ESPENAK, NASA/GODDARD SPACE FLIGHT CENTER

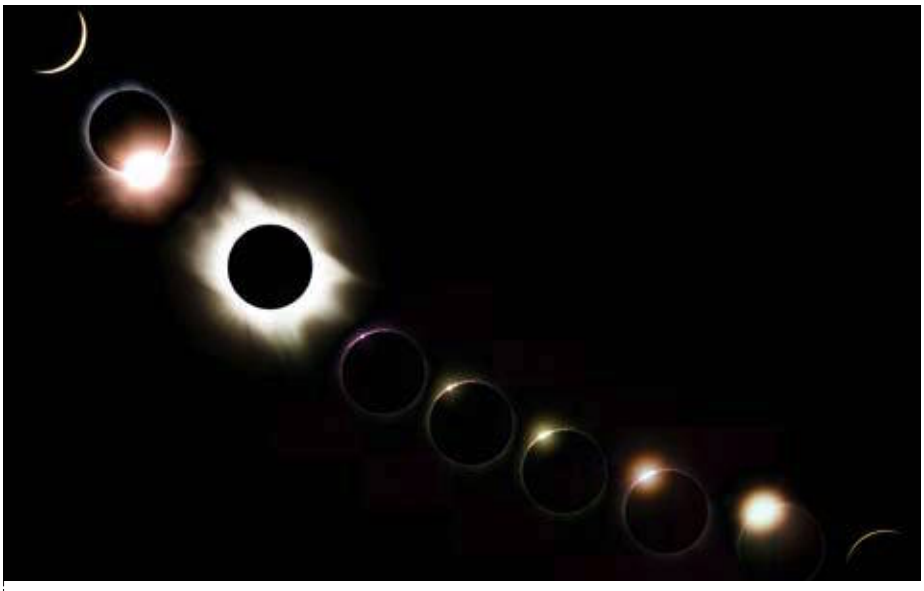
Because long time spans separate eclipses, and because totality lasts such a short time, being prepared is paramount to success.

What makes an eclipse?

A total solar eclipse occurs when the Sun, the Moon, and Earth align, with the Moon in the middle. In a rough sense, this happens every 29.5 days, each time there's a New Moon. The Moon's orbit tilts about 5° to Earth's orbit, so most of the time the Moon lies above or below the center line of the three bodies. Only when it lies on that line does totality occur, and then only for a narrow path where the inner (darkest) part of the Moon's shadow touches Earth.

Regions that fall under the Moon's outer shadow experience a partial eclipse. The closer a location is to the center line, the deeper (percentage-wise) the eclipse.

The Moon must meet another criterion before earthlings experience totality. It can't lie too far from us. If it does, its disk will appear smaller than the Sun's, leaving a brilliant ring in the sky. Astronomers call such events annular eclipses.



THE SOLAR ECLIPSE of March 29, 2006, provided great views along a vast stretch of its path. This sequence shows totality, both diamond rings, and the thin crescent Sun just before and after totality from Side, Turkey. IAN WARDLAW

Location, location, location

August's eclipse arcs across more than 6,200 miles (10,000 km) of Earth's surface. Unfortunately, most of this path lies either in regions difficult to reach or in areas likely to be cloudy. Two locations offer good accessibility — and a better than 50-percent chance of clear skies.

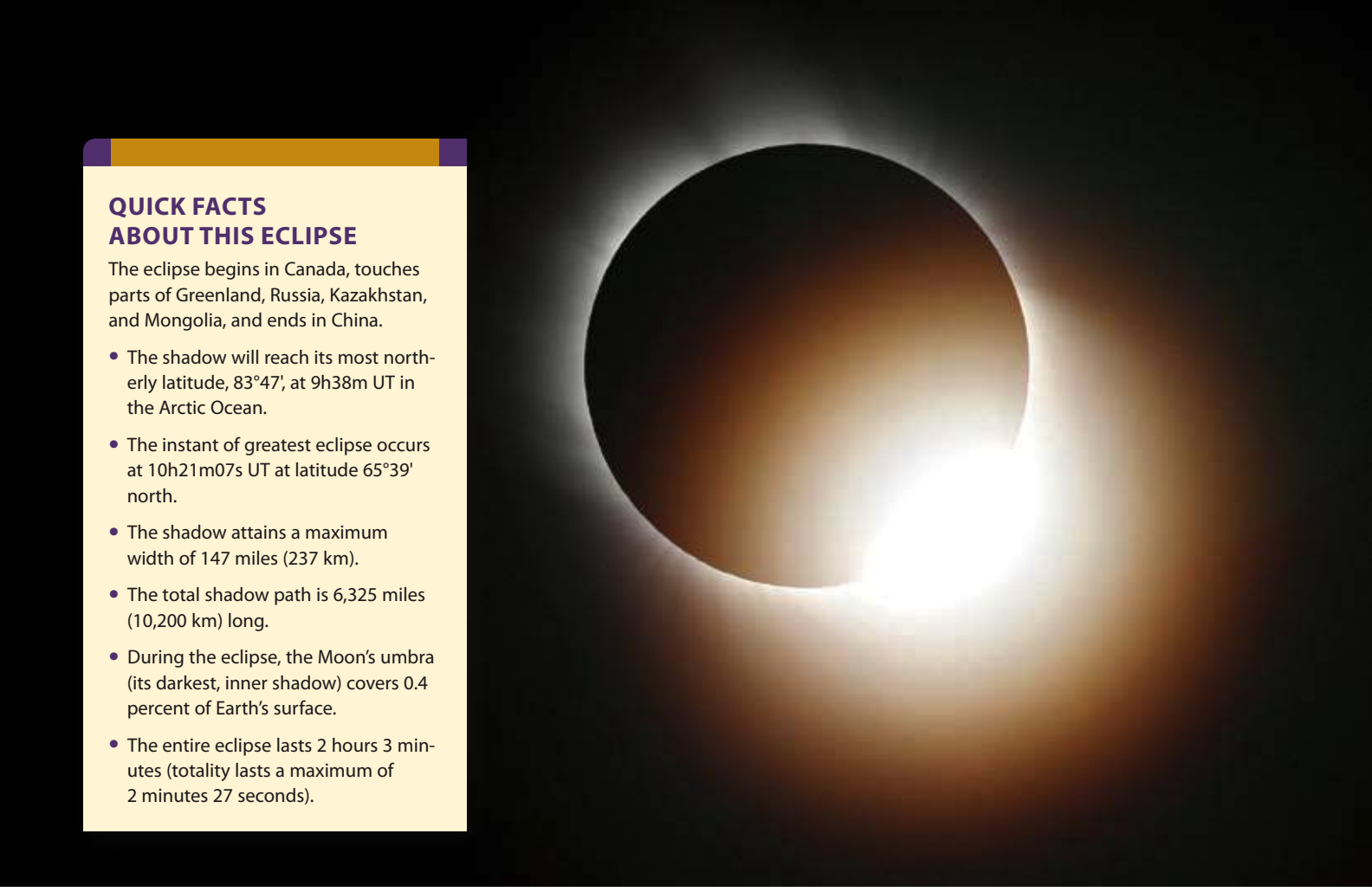
The first location, Novosibirsk, Russia, marks the destination of many tour groups, including *Astronomy*'s own, hosted through MWT Associates of San Jose, California. The second destination is Hami, China. *Astronomy* Editor David J. Eicher and Senior Editor Richard Talcott will lead the

Michael E. Bakich *is a senior editor of* Astronomy. *After August 1, he will have seen 10 total solar eclipses.*

QUICK FACTS ABOUT THIS ECLIPSE

The eclipse begins in Canada, touches parts of Greenland, Russia, Kazakhstan, and Mongolia, and ends in China.

- The shadow will reach its most northerly latitude, 83°47', at 9h38m UT in the Arctic Ocean.
- The instant of greatest eclipse occurs at 10h21m07s UT at latitude 65°39' north.
- The shadow attains a maximum width of 147 miles (237 km).
- The total shadow path is 6,325 miles (10,200 km) long.
- During the eclipse, the Moon's umbra (its darkest, inner shadow) covers 0.4 percent of Earth's surface.
- The entire eclipse lasts 2 hours 3 minutes (totality lasts a maximum of 2 minutes 27 seconds).



THE DIAMOND RING marks the start and end of a solar eclipse's total phase. It occurs as the Moon covers (or uncovers) a tiny vestige of the Sun's disk. ADAM CLAYSON

Novosibirsk trip. The eclipse's center line (where the event's length is greatest) passes a bit west of Novosibirsk, directly over its airport near the town of Ob, which has a population of some 25,000.

Novosibirsk sits in Siberia in central Russia, but forecasters expect no frigid conditions August 1. Both satellite data and surface observations show a 54-percent likelihood of sunshine there. This city has another advantage in terms of getting there: With a population of 2.7 million, it ranks as Russia's third-largest metropolis.

Southwest of the city lies the Novosibirsk Reservoir, Western Siberia's largest artificial lake. Created in 1959, when a dam built on the Ob River began operation, the reservoir measures 115 miles long and 11 miles wide (185 km by 18 km), with an average depth of 30 feet (9m).

This large body of water often quickly breaks up small storm clouds crossing over the reservoir from land. If you have a choice, set up near the shore so the wind blows toward the reservoir, except on the southern end. Doing this could increase your chances of sunshine by as much as 10 percent. Because rain usually arrives with southerly winds, choose the reservoir's north side, near the town of Leninskoye. This small community has a large beach with an excellent southern view.

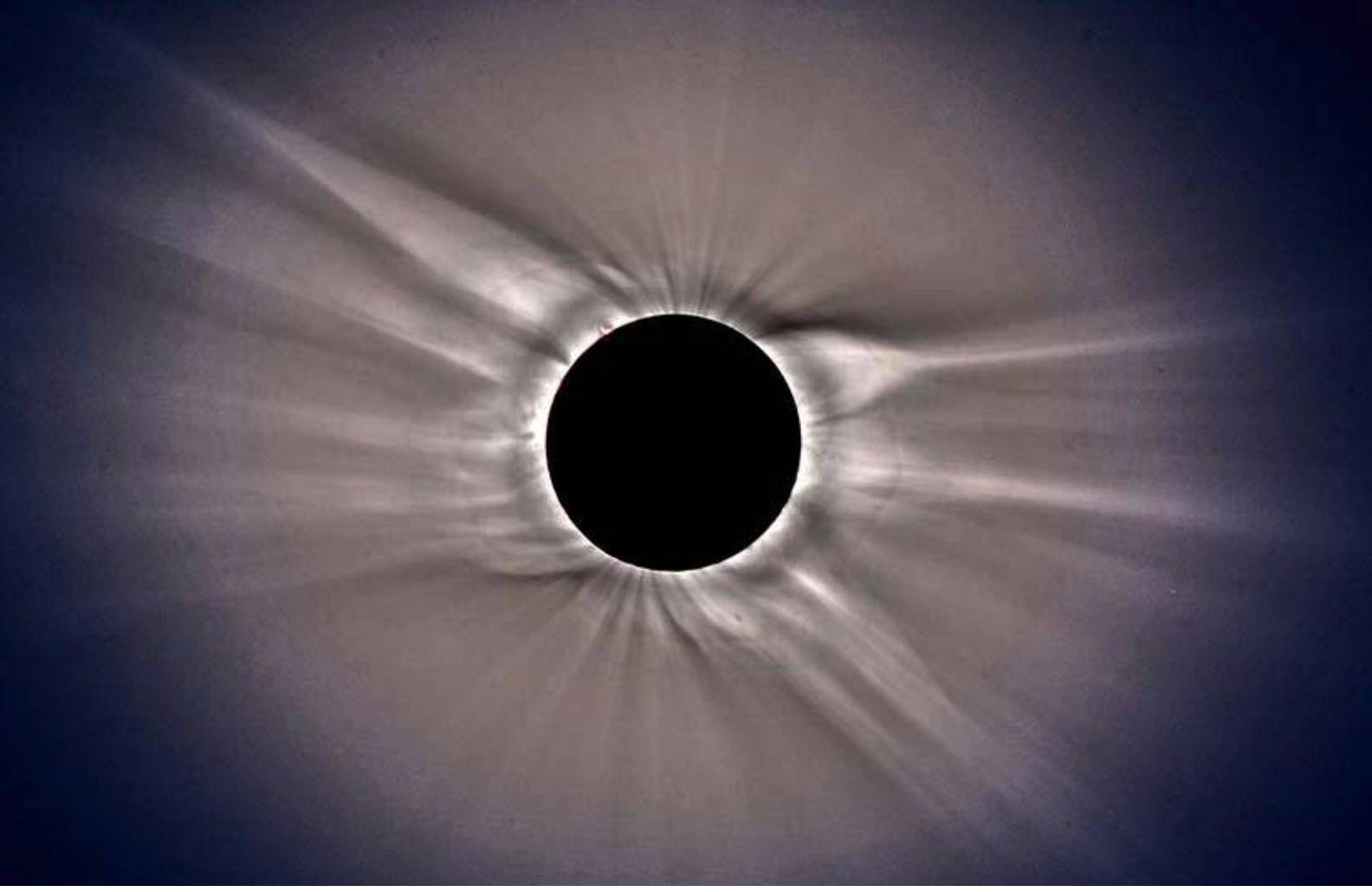
A Chinese alternative

Another good spot for eclipse-watchers will be northern China, just past the Altai Mountains on the Russian-Chinese border. Rainfall is uncommon because the mountains block much of the weather patterns moving through this region, and because the eclipse path passes between the Taklimakan and Gobi deserts.

At Hami, also known as Qumul, sunshine chances reach 76 percent. Hami doesn't lie on the eclipse's central line, but 90 miles (145 km) west of it. Meteorologists warn that Hami's climate data don't reflect the conditions along the center line.

From Hami, it's best to drive an hour east to the Barkol grassland, a plateau just beyond the Karlik Shan (a branch of the Tien Shan Mountains). Keep driving, and you'll find yourself in Yiwu, a city of about 1 million people. Because of its size, and because it has a 48-percent likelihood of sunshine, Yiwu will prove a popular staging

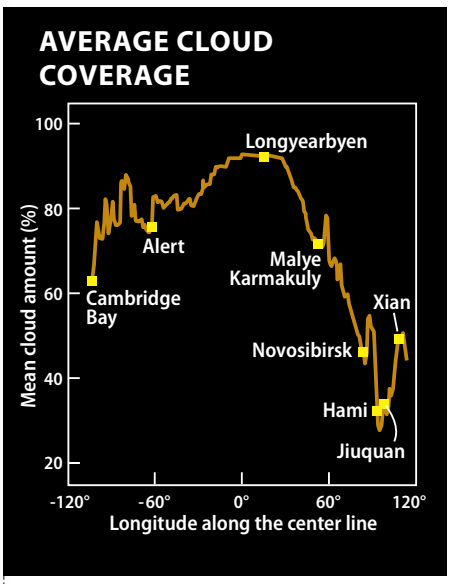
MANY ECLIPSE TOUR GROUPS, including one from *Astronomy*, will head for Novosibirsk, Russia. That country's third-largest city sports a better-than-even chance of clear skies. ECLIPSE FIGURE COURTESY OF FRED ESPENAK, NASA/GODDARD SPACE FLIGHT CENTER



IMAGERS CAN'T CAPTURE ALL OF THE DETAILS in the Sun's corona with a single shot. Here, the photographer combined multiple images to bring out more detail in both the inner and outer parts of the corona. This image of the 2006 eclipse, more than any other, comes closest to showing what the human eye sees during totality. CHARLEY MANSKE

ECLIPSE TERMINOLOGY

Altitude — the distance, in degrees, above the horizon; measured from 0° (the horizon) to 90° (the zenith).
Center line — the midpoint of the Moon's shadow path width, where the eclipse lasts longest.
Chromosphere — a thin layer of the Sun's atmosphere just above the visible photosphere; visible briefly as a flash of red as totality begins and ends.
Corona — the Sun's tenuous outer atmosphere, visible only during totality.
First contact — the moment the partial eclipse begins.
Fourth contact — the moment the partial eclipse ends.
Penumbra — the lighter outer part of the Moon's shadow where you experience a partial eclipse.
Second contact — the moment the total eclipse begins.
Third contact — the moment the total eclipse ends.
Umbra — the dark inner part of the Moon's shadow, where you experience totality.



CLOUDS ARE THE BANE of any eclipse, so travelers carefully monitor past cloudiness over the path of totality. Regarding left-hand numbers 20 through 100 percent, smaller is better. ECLIPSE PREDICTIONS COURTESY OF FRED ESPENAK, NASA/GODDARD SPACE FLIGHT CENTER

point for eclipse-goers. The center line lies 20 miles (32 km) east of Yiwu.

Advice for first-timers

If this is your first total solar eclipse, the best advice is to keep things simple. First, travel light. Not only will you find yourself in unfamiliar settings, but your group may decide to make a last-minute venue change to avoid clouds. A large telescope that requires careful alignment then becomes little more than dead weight.

Instead, take binoculars. I've found 7x50s — which magnify 7 times and have front lenses 50 millimeters (2 inches) in diameter — work best. Even the most rugged don't weigh much. They frame the Sun's corona with a wide field of view and have enough power to reveal any reddish prominences arching above the Sun's limb.

Travelers should carry their own binoculars. Don't waste precious moments passing equipment around during totality's scant 2 or so minutes.

THE AUGUST 9, 1896, TOTAL SOLAR ECLIPSE

Grayer and grayer grew the day, narrower and narrower the crescent of shining sunlight. The sea faded to leaden nothingness.

The circling sea-gulls disappeared with strange cries. One white butterfly fluttered by vaguely. Then an instantaneous darkness leaped upon the world. Unearthly night enveloped all.

With an indescribable out-flashing at the same instant the corona burst forth in mysterious radiance. But dimly seen through thin cloud, it was nevertheless beautiful beyond description, a celestial flame from some unimaginable heaven. Simultaneously the whole northwestern sky, nearly to the zenith, was flooded with lurid and startlingly brilliant orange. The west and southwest gleamed in shining lemon yellow.

Least like a sunset, it was too somber and terrible. The pale, broken circle of coronal light still glowed on with thrilling peacefulness, while nature held her breath for another stage in this majestic spectacle.

Well might it have been a prelude to the shriveling and disappearance of the whole world — weird to horror, and beautiful to heartbreak, heaven and hell in the same sky.

Hours might have passed — time was annihilated; and yet when the tiniest globule of sunlight, a drop, a needle-shaft, a pinhole, reappeared, even before it had become the slenderest possible crescent, the fair corona and all color in sky and cloud withdrew, and a natural aspect of stormy twilight returned. Then the two minutes and a half in memory seemed but a few seconds — a breath, the briefest tale ever told.

This story is from Corona and Coronet *by American writer Mabel Loomis Todd (1856–1932) (Houghton, Mifflin and Co., Boston, 1898).*

AT MID-TOTALITY near Novosibirsk, Russia, the Sun will be 30° high in the west-southwest. The brightest starlike object, Venus, will lie 15° east of the Sun and shine at magnitude –3.9. Next brightest will be Mercury, 3° east of the Sun at magnitude –1.9. The Big Dipper will lie overhead; if you'll be looking for it, be sure to use binoculars. *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

That said, don't spend the whole eclipse looking through binoculars. Take in the view using your eyes. Note the positions of Venus and other bright objects in the darkened sky. Check out the horizon's "sunset" colors surrounding you. Perhaps note how the sky brightens just before totality ends.

Second, don't photograph the eclipse. This may sound unusual coming from *Astronomy*'s photo editor. However, a total eclipse has so many aspects, and is so beautiful, that you'll miss a lot if you're fiddling with equipment. Just enjoy the experience, and plan on photographing your second eclipse. I've given this advice to hundreds of people on eclipse trips, and all I've received is thanks afterward.

Third, be aware of and practice proper eye safety. The Sun is dangerous to look at except through approved solar filters. The only time you can look directly at the Sun is when the Moon covers it during totality.

Many astronomy vendors sell approved filters. As an alternative, head to a welding-supply company and buy a No. 14 welder's glass. If you find yourself without a solar filter, you can view the eclipse's partial phases by using pinhole projection.

THE SUN'S OUTER CORONA extends more than a solar diameter in all directions. This image shows the delicate filamentary structure far from the Sun's eclipsed disk. MIKE D. REYNOLDS

A worthwhile adventure

I've never met anyone who regretted voyaging to see a total solar eclipse, and, I dare say, I never will. Do whatever it takes to see darkness at noon, and you'll experience nature's most spectacular show. In the words of one of my longtime observing buddies, "Just get there!"

Fill your summer nights exploring easy-to-find constellations, bright stars, and the Milky Way. /// **BY MICHAEL E. BAKICH**

Find your way through the summer sky

Use the star map in the center of the magazine with this story. Bold words are objects you'll find on the map.

If you want to begin observing the sky,

start in the summer. Lots of bright stars populate the sky then, guiding you to the constellations that contain them. The brightest part of the Milky Way arches from north to south. In that star-packed region, deep-sky treasures visible through binoculars abound. Plus, it's warm outside, helping you to observe longer.

High in the northwest in the evening, seven stars form the Big Dipper. This well-known group daily circles the North Star, **Polaris** (Alpha [α] Ursae Minoris). The two stars at the end of the Dipper's bowl — the Pointer Stars — point to Polaris. The Big Dipper, however, is not a constellation. It's part of **Ursa Major** the Great Bear.

SCORPIUS THE SCORPION sits low in the summer sky for northern observers. The bright star Antares (Alpha [α] Scorpii) marks the Scorpion's heart. Many clusters and nebulae populate the Milky Way, which runs through Scorpius' tail. ALL IMAGES: BILL AND SALLY FLETCHER

Notice the description of Polaris in parentheses. You'll see a Greek letter, its symbol, and the possessive form of the constellation name. Only a few hundred stars have proper names, but about a thousand have Greek letters associated with them. This practice began with German mapmaker Johann Bayer (1572–1625) in his star atlas *Uranometria*, published in 1603. Astronomers have used his stellar designations ever since.

Use the curve of the Big Dipper's handle to lead you south to **Arcturus** (Alpha Boötis), the brightest star in the constellation Boötes the Herdsman. Arcturus glows orange, indicating it's a cool star. It ranks as the fourth-brightest nighttime star, and the brightest in the northern half of the sky.

Overhead, three bright stars form summer's second-easiest star picture (next to the Big Dipper) — the Summer Triangle. Each is the Alpha star in its constellation. The brightest is **Vega**, in **Lyra** the Harp; next brightest is **Altair**, in **Aquila** the Eagle; the third is **Deneb**, the star marking the tail of **Cygnus** the Swan.

Cygnus contains the asterism of the Northern Cross. Albireo (**Beta [β] Cygni**) lies at the base of the cross. This object is one of the top 10 showpieces for small telescopes. Albireo is a colorful double star, wide enough that even 10x50 binoculars will separate the pair. Color perception is

Michael E. Bakich *is a senior editor of* Astronomy. *Summer is his favorite time to observe constellations and bright stars.*

unique among humans, but most observers see these stars as gold and sapphire-blue.

Just outside Cygnus' Milky Way region lies Lyra. In the same binocular field as Vega is **Epsilon (ε) Lyrae**, a wide double star with two equally bright components. Amateur astronomers know Epsilon Lyrae as the Double Double because each member is itself a double star. You can split each pair by using high magnification through a 2.4-inch (60-millimeter) scope.

Try finding the Coathanger asterism through your binoculars. About halfway between Albireo and Altair, the Coathanger is a line of six stars with a curve of four stars (the hook) protruding from its center.

A bit west of the Summer Triangle lies **Hercules**, the legendary hero. This constellation contains one of amateur astronomy's main tourist sights — the Hercules Cluster (**M13**), the finest globular star cluster in the northern sky. M13 lies along one side of the Keystone, a crooked box of four medium-bright stars that mark the Hero's body.

You'll find the Keystone about two-thirds of the way from Arcturus to Vega. You can glimpse M13 with your unaided eyes under a dark sky, but it looks better through binoculars, where it will appear half the width of the Full Moon.

The "M" before the number 13 stands for "Messier object." French comet-hunter Charles Messier (1730–1817) compiled a list of 109 such objects. Through the small telescopes of his day, such objects resembled comets. He wanted other observers to realize they weren't comets. Through today's scopes, however, Messier's list contains many of the finest celestial targets.

Hercules stands head to head with another giant in the sky, **Ophiuchus** the Serpent-bearer. Ophiuchus is a man entwined by a large snake — Serpens — the only constellation divided into two separate parts. In his left hand, Ophiuchus holds the snake's head, **Serpens Caput**. To Ophiuchus' east is **Serpens Cauda**.

TWO OF THE SUMMER TRIANGLE'S THREE BRIGHT STARS appear in this image. Brilliant Vega (Alpha [α] Lyrae) sits at the right edge and blue Deneb (Alpha Cygni) sits above center near the red North America Nebula (NGC 7000).

THE BIG AND LITTLE DIPPERS occupy prime real estate in the constellations Ursa Major the Great Bear and Ursa Minor the Little Bear. Use the Big Dipper's "pointer stars" to lead you to Polaris (Alpha [α] Ursae Minoris), the North Star.

Ophiuchus, in turn, stands on the body of **Scorpius** the Scorpion. Because Scorpius and neighboring Sagittarius lie in the southern part of the sky, thick air layers dim their glory from northern latitudes. Everyone should be able to find **Antares** (Alpha Scorpii), the bright star marking the Scorpion's heart. Antares is a red supergiant 400 times larger than the Sun.

Next to the Scorpion's stinger lie two glorious open star clusters, **M6** and **M7.** M6, popularly known as the Butterfly Cluster because of its shape, appears slightly elliptical, and its brightest star is an orange giant that varies in brightness.

M7 is easy to spot with your naked eyes as a bright knot in the southern Milky Way. Through binoculars, M7 appears more than twice as wide as the Full Moon. M7's central stars are arranged in an X, while the outliers form a triangle.

East of Scorpius lies **Sagittarius**, toward the center of our galaxy. Sagittarius has many wonderful deep-sky objects within its borders. Start with the Lagoon Nebula (**M8**), a milky glow 3 Moon-diameters long with a dark rift down its center. Near M8 sits **M22**, a fine globular cluster. Under a dark sky, binoculars show it as a woolly ball about two-thirds the Moon's diameter.

Finally, move north along the Milky Way into **Scutum** to encounter the Wild Duck Cluster (**M11**), one of the summer sky's best clusters. English observer William Henry Smyth (1788–1865) called M11 the Wild Duck Cluster because it's V-shaped, like a flight of wildfowl. Small telescopes show the V has a brighter star at its apex.

Once you learn the main constellations and bright stars in the summer sky, it's an easy transition to the other three seasons. In a short time, you'll be locating lots of great objects to share with others. And you won't even need a star map.

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INDEX *of* ADVERTISERS

20-20 Telescopes 76
Adirondack Video Astronomy 76, 77
ADM 77
Adorama 15, 19
Anacortes Telescope & Wild Bird 75, 76
Aridian Publishing 60-61
Ariel Optics 75
Ash Manufacturing 76
Astro Haven 17
Astro-Physics 75
Astronomics 5
Astronomy.com 49, 72
Astronomy magazine 72
Astronomy magazine Sweepstakes 48, 49
Astronomy Technologies 9
Astrozap 72
Aurora Astro Products, LLC 77
Beam of Light Technologies 74
Beta Electronics 76
Big Bang Astronomy Shop 75
Bob's Knobs 74
Celestron 82
Denkmeier Optical 76
Earthwin Optical, LLC 77
Focus Camera 72, 76
Glatter, Howard 76
Grossman Bathsheba 75
Jewelry Designs For Men 77
Jim's Mobile, Inc. 19
Khan Scope Centre 77
Let's Talk Stars 72
Lightbuckets 19
Luckyduck.com 75
Lumicon 17
Lunt Solar, LLC 49
Math Tutor DVD 77
Mayhugh Travel 74
Meade Instruments Corporation 2, 3
Moonlite Telescope Accessories 77
Newport Glass Works 75
Observatory, The 75
Obsession Telescopes 77
Oceanside Photo & Telescope 17, 27
Optical Mechanics, Inc. 76
Orion Telescopes & Binoculars 4
Owl Services 74
Photonic Cleaning Technologies 77
Rainbow Symphony 76
Scope Buggy 77
ScopeStuff 76
SCS Astro 74
Seymour Solar 77
Sirius Observatories 74
Sky Instruments 74
Smartastronomy.com 75
Solarscope 77
Stargazers Inn 77
Starmaster Portable Telescope 74
Stellarvue 74
Surplus Shed 74
Technical Innovations 9
Tele Vue Optics, Inc. 81
Telescope Stability Systems 77
The Teaching Company 50
Thousand Oaks Optical 74
Vixen Optics 51
Woodland Hills Cameras & Telescopes 9
www.bigbinoculars.com 75

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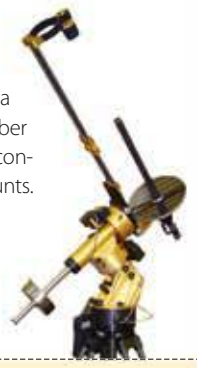

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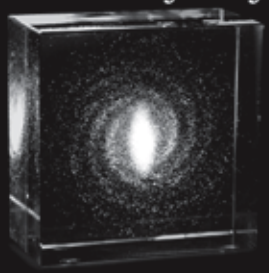

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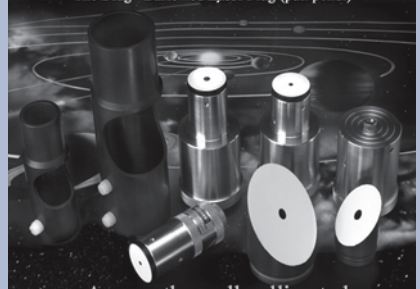

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THE BUTTERFLY CLUSTER (M6) (3-inch Tele Vue 76 at f/6.3, SBIG ST-10XME CCD camera, RGB image with all exposures 20 minutes)
/// **LAWRENCE JOHNSON, KATHY ORTEGA, AND ADAM BLOCK/NOAO/AURA/NSF**

A BRIGHT SUMMER STAR CLUSTER

Off the Scorpion's tail

The constellation Scorpius the Scorpion is an easy find for observers worldwide. Just off the Scorpion's two "stinger" stars lie two open clusters, the Butterfly Cluster (M6) and Ptolemy's Cluster (M7). Because magnitude 2.8 M7 outshines magnitude 4.2 M6, astrophotographers generally aim for M7. But, as this image shows, M6 has much to offer. From a dark site, it's easy to see with your naked eyes. You'll spot two dozen stars through binoculars and about 75 stars through an 8-inch or larger telescope. The cluster covers 25', a bit less than the Full Moon's area.

SPIRAL GALAXIES NGC 3729 (upper left) and NGC 3718 form a spectacular pair of 11th-magnitude galaxies. This duo lies 3° west of Phecda (Gamma [γ] Ursae Majoris). You'll need at least a 16-inch telescope to see the details shown here. (12-inch Meade LX200R Schmidt-Cassegrain telescope, SBIG ST-10XME CCD camera, LRGB image with exposures of 155, 60, 45, and 60 minutes, respectively) /// **RUBEN KIER, ORANGE, CONNECTICUT**

THE ESKIMO NEBULA (NGC 2392) in Gemini is a 9th-magnitude planetary nebula. You can see its double shell even through medium-sized telescopes. (9-inch TMB apochromatic refractor at f/9 and f/18, Starlight Xpress SXVF H36 CCD camera, LRGB image with exposures of 72, 20, 20, and 20 minutes, respectively) /// **DIETMAR HAGAR, ST. JOHANN AM WIMBURG, AUSTRIA**

THE ROSETTE NEBULA (NGC 2237–9) in Monoceros combines nebulosity with an open star cluster. Note the variation between the central pink and the outer deep-red hues. (3.2-inch Stellarvue apochromatic refractor at f/4.8, Canon XTi DSLR camera, ISO 800, three 10-minute exposures) /// **CHRIS SCHUR, PAYSON, ARIZONA**

EMISSION NEBULA NGC 3199 in Carina surrounds Wolf Rayet star 18. The bubble's shape distorts as the star plows through interstellar gas. This causes a shock front along the brighter, western edge. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, Apogee Alta 16803 CCD camera, Hα/SII/OIII image [mapped to green, red, and blue, respectively] with exposures of 240, 180, and 120 minutes, respectively) /// KEN CRAWFORD, RANCHO DEL SOL CAMINO, CALIFORNIA

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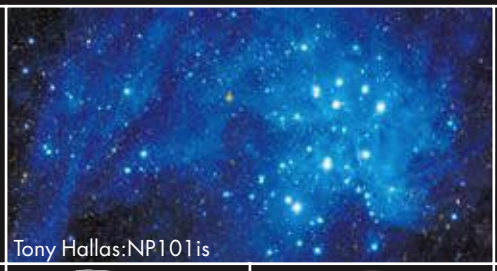
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